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INTELLIGENT SEMANTIC QUERY OF NOTICES TO AIRMEN (NOTAMs)

BBN Technologies

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14. ABSTRACT
The goal of this project was to develop computer technology to make NOTAM information available to Air Mobility Command (AMC) flight personnel (flight planners, managers and pilots), in a more timely and effective way. NOTAMs are notices containing information on the conditions, or changes to, aeronautical facilities, services, procedures, or hazards, which are essential information for flight operations. This project was part of the AFRL/IF Integrated Flight Management (IFM) Advanced Technology Demonstration (ATD), whose goals were to "….advance the search, retrieval, handling, use and dissemination of raw resource data …required by Air Mobility Command (AMC) as it pertains to their mission planning and the optimal use of available mobility resources." To automate the search, retrieval, and dissemination of NOTAMs, it is essential that the critical parts of the information content of NOTAMs be made "understandable" to computers. There are two components to this, parsing which extracts key information from NOTAM free text and representation which provides formal display of the extracted NOTAM content. This work developed a new parsing system and innovative displays to address the needs of Mobility flight planners. Though originally developed strictly for AMC, this work has been successfully transitioned beyond just AF and DOD applications.

15. SUBJECT TERMS
NOTAMs, AFRL/IF Integrated Flight Management (IFM), Advanced Technology Demonstration (ATD), Air Mobility Command (AMC)

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Abstract

The goal of this project was to develop computer technology to make available to Air Mobility Command (AMC) flight personnel (flight planners, managers and pilots), in a more timely and effective way, the flight-safety critical information contained in a set of internationally distributed text messages known as Notices to Airmen (NOTAMs). Briefly put, *NOTAMs are notices containing information (not known sufficiently in advance to publicize by other means) concerning the establishment, condition, or change in any aeronautical facility, service, procedure, or hazard, the timely knowledge of which is essential to personnel concerned with flight operations.* This project was initiated as part of the Integrated Flight Management (IFM) Advanced Technology Demonstration (ATD), whose goals were to "….advance the search, retrieval, handling, use and dissemination of raw resource data and refined information that is required by Air Mobility Command (AMC) as it pertains to their mission planning and the optimal use of the available mobility resources."

In order to automate the search, retrieval, and dissemination of NOTAMs, it is essential that the critical parts of the information content of NOTAMs be made "understandable" to computers. However, NOTAMs were never designed to be understood by computers – they are essentially free-text messages written by people in over 160 countries, and intended to be interpreted by other human beings. In order to make such free text understandable by machines, there are two challenges –

1) *The NOTAM parsing problem* – extracting key information from free text, despite wide variations in form (syntax) and content (semantics) and non-trivial numbers of errors, both typographical and otherwise
2) *The NOTAM representation problem* – providing a formal representation of the extracted information content the will facilitate reasoning by a computer system to determine whether a given NOTAM is relevant to a given flight (e.g. do the geographical and three dimensional regions covered by NOTAM intersect the flight plan, is the NOTAM in effect at the expected time of the flight, and is the change in airspace/facility characteristics likely to affect the type of aircraft involved, performing the specified mission).

At the time this research was started, the only "parsing" that had been done of NOTAMs was simple string pattern matching, looking for single words such as "CLOSED", and the particular codes that were contained as part of the message. Although NOTAMs are supposed to be issued in English (no matter what country issues them), no attempt had been made to use sophisticated natural-language parsers to extract information. The pattern matching approaches produced large numbers of "false alarms" (indications that NOTAMs were critical for given flights), and tended to swamp AMC personnel.

In order to solve the NOTAM parsing problem we had to develop a new parsing system, employing and extending ideas developed by the information-extraction community, rather than on classical computational linguistics. The initial expectation of this project had been that we would be able to take a computational-linguistics approach, and modify existing English-language parsers to handle the NOTAM text.

After examining the first set of 30,000 NOTAMs, it became clear that this would not be feasible. The vocabulary in NOTAMs was highly specialized, filled with jargon and abbreviations not covered by standard parsers. They were filled with non-standardized domain-specific phrases describing flight procedures and equipment, geographical regions, altitude restrictions, etc. It also became clear that the number of variant spellings of key words was quite high, and that misspellings and typos were common. Punctuation was dropped and added and used in non-standard ways. Finally, it became clear that even ignoring errors and specialized phraseology, the basic structure of the language was not in general like standard English. Because native speakers from 160 countries were attempting to communicate in English, the result was linguistically less like a standard language like English or French and more like what linguists term a "pidgin." To handle these and other problems we developed a parsing technology based on the concept of "cascaded finite-state automata", which made it possible to quickly extract complex local phrases without requiring that the overall structure of the NOTAM looked anything like a sequence of well-formed sentences. The resulting parser, which we call FIST (FInite State Transducer), is not only robust in response to the errors discovered in the worldwide set of NOTAMs, but is extremely fast (parsing 8 NOTAMs, with average length of more than 50 "words", in under a second on a 2.1 Ghz Pentium M processor). Additionally, because the definition of the airspace is constantly changing, new vocabulary is added and old words retired on a monthly basis, and the information specifying this is buried in databases issued by various agencies such as the National Geo-Spatial Intelligence Agency (NGA).

This project has had a number of important spinoffs. The project was originally intended as primarily a research and prototyping effort to determine how far we could go in meeting AMC's needs by attacking the NOTAM parsing and representation problem. However, early progress in the parsing effort, led to BBN producing an unplanned, unfunded connection to the GAMAT Global Weather Management situation awareness and decision support project being performed for AFRL's Human Effectiveness Directorate in support of AMC. AFRL/IF and AFRL/HECS enthusiastically supported this collaboration after the initial demonstration of what could be done, and this in turn led to its integration into a major set of Air Force demonstrations called the Global Conops Synchronization demonstration (or the "CAF-MAF" demo – the Combat Air Force/Mobility Air Force information interchange demonstration). This demonstration led to requests by senior Air Force personnel that this capability be evaluated as part of the Air Force JEFX 2004 Exercise. Success in this exercise led to the decision to incorporate some form of this NOTAMs parsing capability into a Common Component of the Joint Mission Planning System (JMPS), and to requests (and funding) by NGA to use this capability to help them maintain models of vertical obstructions in the airspace. Outside the DoD, the FAA and commercial aviation organizations like Jeppesen expressed interest in this capability, and as part of the JMPS program this capability is being tied in to the FAA NAIMES (NAS Aeronautical Information Management Enterprise System) system. Finally, EUROCONTROL (the European Organisation for the Safety of Air Navigation) has expressed interest in this technology and requested a briefing on the system in September 2004.

The success of this project has been exciting for its participants and sponsors, but the resulting move from research effort to deployment leads to concerns that must be raised strongly here. It is important to note that while this project has transitioned capability to various other Air Force and Department of Defense programs, ***the NOTAMs parsing problem and the NOTAMs representation problem are not fully solved.*** In fact, given the extreme variety in types of language used within NOTAMs, the level of errors introduced by human NOTAM writers, and the constantly changing nature of the airspace (and hence airspace announcements), we believe that ***no fully automated system will be able to extract and correctly represent all of the critical information content of every NOTAM issued.*** Thus it should not be expected that the current NOTAMs parser produces error-free output for all NOTAMs, ***and it is critical that the NOTAMs parser be used as part of a combined human/automated system. Trained human beings must continue to take responsibility for safety-of-flight issues.*** It is important to bear in mind that the goal of the project (and thus the resulting system) is to provide robust enough parsing so that the overall operations of AMC can be improved by reducing workload associated with distributing NOTAMs.

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Introduction

This project was initiated as part of the Integrated Flight Management (IFM) Advanced Technology Demonstration (ATD), whose goals were to "….advance the search, retrieval, handling, use and dissemination of raw resource data and refined information that is required by Air Mobility Command (AMC) as it pertains to their mission planning and the optimal use of the available mobility resources."

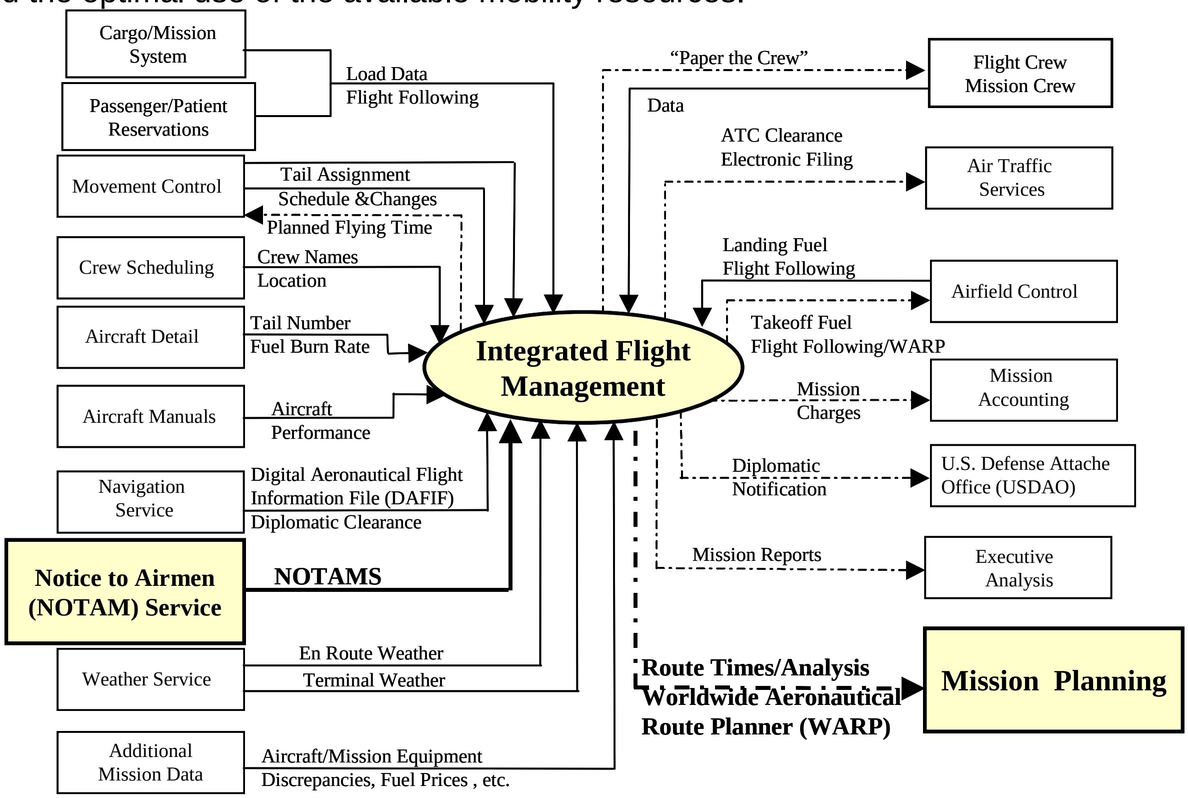

Figure 1: Information flow required for planning AMC missions

As noted in the diagram from the draft Mobility 2000 Concept of Operations, a key part of the information flow required for planning and executing AMC missions consists of Notices to Airman (NOTAMs). In order to understand this project, it is important to understand what NOTAMs are, why they are critical to AMC operations, and what challenges they pose to automated processing.

NOTAMs: Safe, efficient and effective flight planning, flight management and flight operations by AMC (as well as other Air Force commands, other DoD components, and the aviation community in general) requires timely and up-to-date knowledge of the conditions and characteristics of aviation facilities, procedures, and services, as well as the existence and characteristics of hazards to flight. The bulk of this information is

known in advance, stable over long periods of time, and is published in standard, well-defined publications reissued periodically at standard times by various national and international aeronautical organizations (e.g. the Federal Aviation Administration (FAA) and Department of Defense in the United States, the International Civil Aviation Organization (ICAO), EUROCONTROL (the European Organization for the Safety of Air Navigation) and the national aviation authorities of most member nations of the United Nations.).

It is the responsibility of each pilot (and other members of the flight planning and management community such as AMC flight managers and planners) to read such official publications and stay abreast of all of this information for all airspace through which a sortie is planned to navigate and facilities it is expected to use. However, there are always unanticipated and/or short-term changes in these conditions and characteristics which must be transmitted on short notice to pilots and others by electronic means. This function is handled by NOTAMs.

NOTAMs are time-critical, safety-critical announcements of temporary changes to global flight conditions. They cover much of the aerospace flight environment such as the condition and availability of many airport facilities (including runways, instrumentation, fuel, etc), flight / navigational aids, restrictions on airspace (weather, political, commercial, etc) and a great variety of air traffic regulations and flight related concerns. *There are around 30,000 active NOTAMs at any given time, updated at a rate of several thousand per day.* ***– the key operational question is how to make sure aircrews and planners get the right information in a timely fashion.***

The particular goal of this project was to address AMC's critical need to quickly identify and flag mission impacting NOTAMs to the Tanker Airlift Control Center (TACC) Flight Manager (FM).

To get some feeling for the variety of NOTAMs that must be handled, we can look at various distributions of NOTAMs, e.g. by country and by topic. On a typical day, while there may be up to 160 countries represented, out of 30,000 NOTAMs, there are 10,000 US NOTAMS, 3000 Italian, 1400 German, and 1000 British NOTAMs. This distribution has important consequences because experience has shown us that there are noticeable and strong variations in the way that various issues are reported, differing by nation (and many regions, airfields and probably even particular human NOTAM reporters). The fact that over half of the NOTAMs issued come from a handful of countries simplifies things somewhat, but it leads to a situation where there is a long "tail of the distribution" (rare, but actually seen variations) of different ways to express common issues.

To assess distribution by topic, we can make use of human entered QCODEs contained in many NOTAMS. These are five character codes defined by ICAO (the International Civil Aviation Organization) and extended by the US Department of Defense. ICAO and DoD requirements specify that all NOTAMs should contain QCODEs, though this requirement is clearly not followed universally. These QCODEs are supposed to represent the overall topic of the NOTAM. Appendix 0 lists the official ICAO QCODEs. On a typical recent (2006) day with about 30,000 active NOTAMs there were 7500 NOTAMs without QCODEs, and 3000 with the QCODE "QXXXX" which is

supposed to mean “no QCODE topic applicable, reported in plain text” but by inspection seems to most often mean “the author didn’t have time to look up the appropriate QCODE”. The next most common QCODEs are “QOL..” (2000) and “QOB..” (1300) which talk about vertical obstructions (QOB..) and the lights on them (QOL..), followed by “QMRLC” - runway closed – (700) , “QPICH” -- instrument procedure changed (650), followed by “QFAXX” – an unspecified fact about the airfield as a whole – (500). Again, there are some QCODEs for which we have a lot of data for how the content is represented in the plain text, but there is a huge tail of low likelihood variations that a system must deal with.

If QCODEs were universally applied and accurate, this would go a major part of the way in identifying critical NOTAMs. Unfortunately, as indicated above, no more than 65% of NOTAMs have meaningful QCODEs, and closer inspection indicates that of those NOTAMs with QCODEs, there are problems in > 10% (inaccuracies, or missing information due to use of the “XX” suffix which means “unspecified report”, or NOTAMs which report multiple facts, but are constrained to use only one QCODE – e.g. the modification of an instrument procedure caused by the existence of a temporary or permanent vertical obstruction).

The NOTAM Parsing (and Representation) Problem: At any given time, there are on the order of 30,000 NOTAMs in force (active NOTAMs), with approximately 3,000-4,000 NOTAMs issued each day (and an equivalent number being cancelled or expiring). For an organization like AMC with a global and constantly changing mission, the problem is how to keep flight personnel abreast of the relevant changes to the airspace, and to recognize when planned or currently flying missions may be impacted by such changes, without drowning already heavily burdened flight managers and pilots with unrelated NOTAMs. The goal of this project was to determine how much could be done with automated parsing and knowledge representation technology to meet these needs.

The Operation Context of the Problem

At the start of this project, the process of getting NOTAM information relevant to an AMC sortie was still a primarily manual operation. This has remained true even with the increasing use of computerized systems such as Integrated Management Tool (IMT) by flight managers, and access to NOTAMs from the Defense Internet NOTAM Service (DINS) web-based service. The process of “papering the crew”, which includes providing the crew with the collection of NOTAMs relevant to their sortie, requires substantial manual attention from the flight manager. We indicate some of the dimensions of this problem by using material from a briefing by AMC personnel. Even after the operational installation of the IMT system the process looked like the following:

Given a flight plan provided within IMT, the FM uses IMT to pull up NOTAMs from DINS. This is a manual data pull that requires continual polling to remain current.

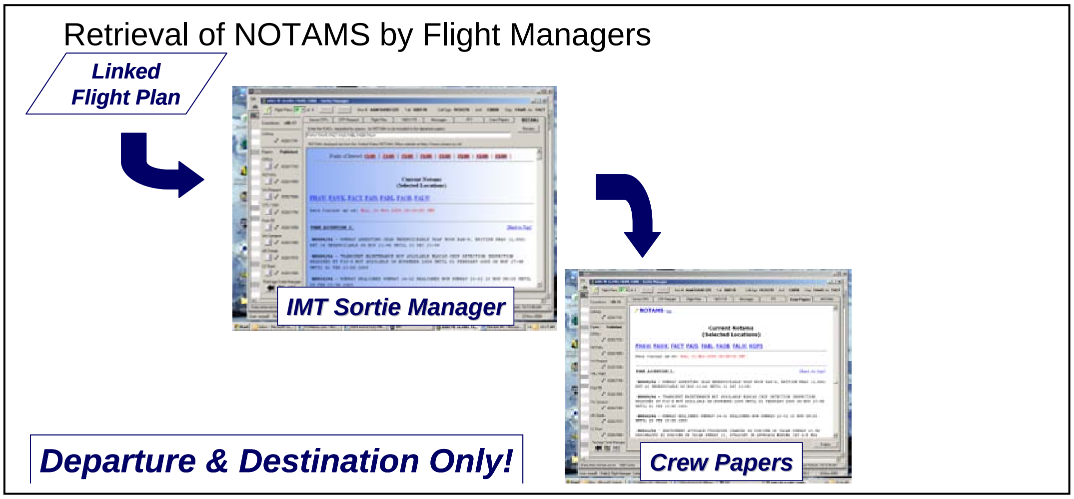

Figure 2: Retrieval of NOTAMS by Flight Managers

The DINS query mechanism is primarily limited to query by issuing location, and this is primarily used to find NOTAMs for the Departure and Destination International Civil Aviation Organization (ICAO) codes only. ICAO codes are 4-letter airport identifier codes that uniquely identify individual airports worldwide. Usually, the first two letters of ICAO codes identify the country. However, ICAO codes for airports in the continental United States begin with a "K", and are followed by the three-letter International Air Transport Association (IATA) airport code that airline passengers are used to seeing.

NOTAMs for selected (primary) alternates can also be added. to make sure of catching all NOTAMs that might affect the flight. Additionally the FM can request NOTAMs issued by various other offices, such as the individual Flight Information Region (FIR)/Upper Flight Information Report (UIR)/Air Route Traffic Control Center (ARTCC) regional centers controlling the regions that the flight goes through, as well as more general NOTAMs such as those issued by KFDC (Washington, DC), ATTA, ATTN, ATTC, ATTP, KZZZ and KGPS.

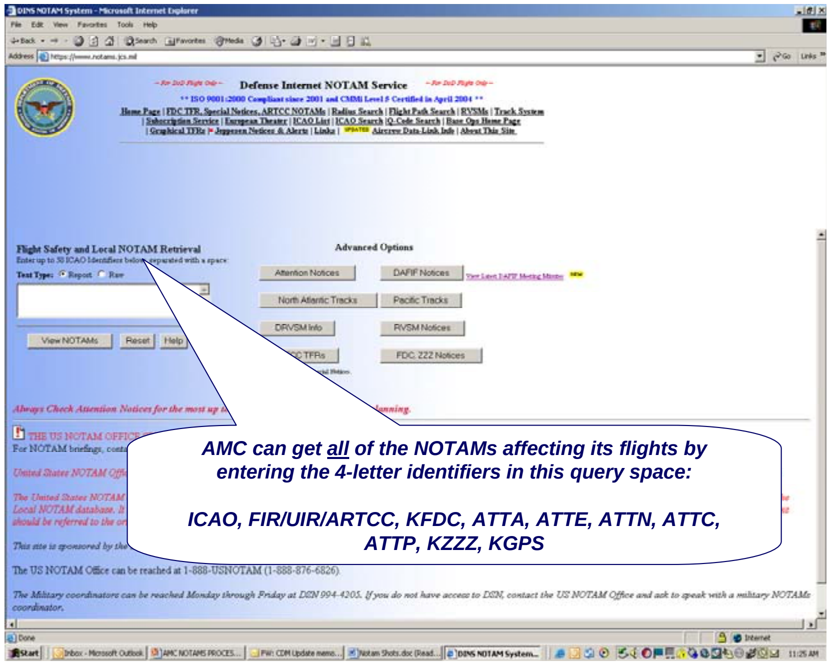

Figure 3: The DINS Web Interface

To simplify retrievals, DINS has a geographic search mechanism, but this is based on the issuing location as well, and is restricted to queries based on great circle routes. There is no mechanism to make use of detailed computer readable flight plans to retrieve NOTAMs along the route of flight.

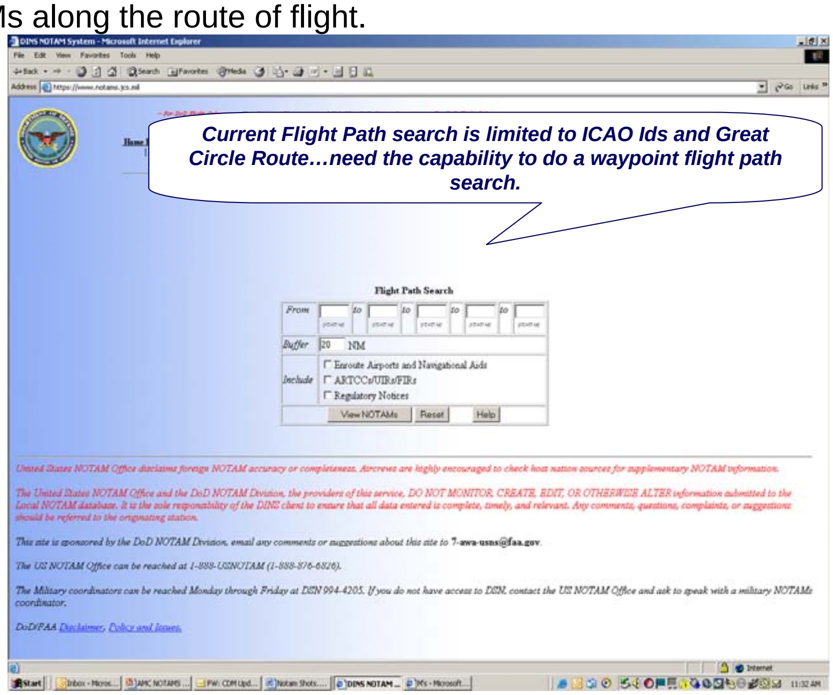

Figure 4: Using the DINS web interface via ICAO Ids

Manual information pull with query limited to location limits automating the process for a number of reasons:

- Because there is no way to filter the NOTAMs based on spatial or temporal extent, or on classes of airspace restrictions or equipment/facilities/procedures impacted, the choice is often between providing too few NOTAMs to the crew, or too many. It might seem that providing a larger set of NOTAMs than are actually relevant would be appropriate as a way to avoid missing critical NOTAMs, in practice this leaves it up to the crew to search through what can be hundreds of NOTAMs in a flight over Europe, almost all of which are irrelevant to the actual flight path.
- There is no way, short of constant polling by the FM to find new NOTAMs that become relevant to the flight, or to find NOTAMS that are no longer relevant. Note that aircrews do not receive in-flight updates of new or changing NOTAMS.
- During the (sometimes quite long) period between initial planning and the beginning of FM operations (typically around 24 hours before the launch of the sortie), NOTAMs that might require re-planning of the sortie are not monitored. Thus:
    - Missions planned months prior to execution may become obsolete when relevant NOTAM information changes
    - Contingency planning is required when transitioning from planning to execution.

Project Goals

This project was initiated as a one-year effort with an original period of performance of July 11, 2002 through July 10, 2003. The focus of this project was to determine the feasibility of using parsing technology to solve the NOTAM problems described above. We proposed to develop techniques that could be used to reduce the workload of the AMC FM and provide focused information to flight crews, by developing a set of automated tools to translate the message based, free text (NOTAM) information into machine-representations suitable for presentation to automated decision systems. This project was conceived to be the initial step in producing a more complete Intelligent Distribution and Inference system for NOTAMs, extending the concept introduced in the AFRL Intelligent Distribution of NOTAMs (IDiON) system, but it was not in and of itself expected to produce such a full system.

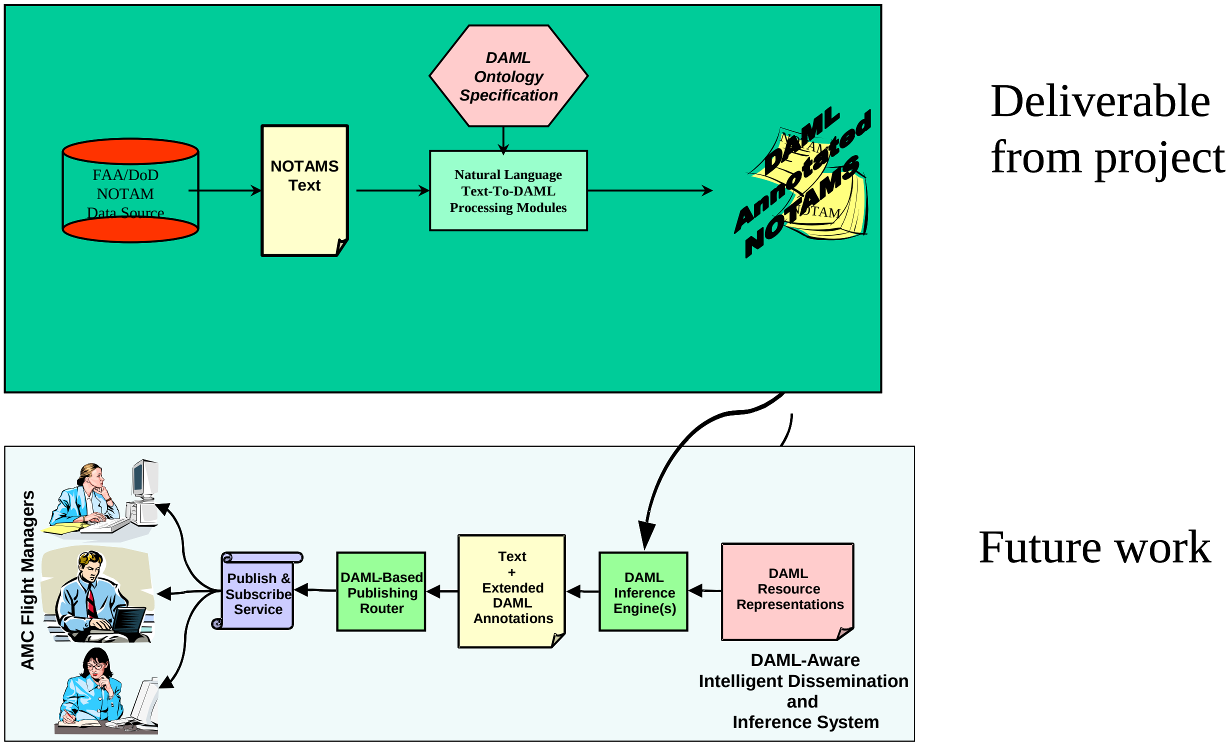

Figure 5: ISQ NOTAMs project goals and efforts beyond

The original project tasks with commentary:

- **Establish the specific requirements including the sets of NOTAMs to be translated, the data sources to be used and the decision support system(s) within the Mobility Air Force Research and Development Facility (MAF/RDF) to be used in the demonstrations.**
    - It was recognized in the project proposal that it would be impossible to produce a system to completely parse all NOTAMs within the available resources, so the goal was to determine a sub-set of the NOTAM stream that would provide value to the FMs and would demonstrate the potential value of a more complete solution.
    - The original concept was to prototype this by integration with the AFRL IDiON system, but as the development of that system was a limited duration AFRL/IF in-house project, the government requested that we develop a more generally applicable interface to allow for use of the base technology in any of a number of potential applications.
- **Based on the requirements identified, develop and implement an ontology to represent the NOTAM information content.**
    - This was originally characterized as a DAML+OIL ontology, the existing US/EU standard for web ontologies. As the project continued, this was changed to make use of the World Wide Web Consortium (W3C) Web

Ontology Language ("OWL") standard[1] that was developed out of DAML+OIL.

- **Develop natural language processing modules to translate NOTAM text into the chosen ontology.**
- **Develop a Graphical User Interface (GUI)-based ontology annotation viewer and editor to allow a user to rapidly review and revise the annotations produced by the automated components**.
- **Design and develop and infrastructure fitting the various components, the stored NOTAM ontology, the natural language processing modules and the GUI viewer/editor together and make it accessible in a general manner to support other automated systems**.

This initial project was extended in a number of ways as it became clear that the resulting technology could be used by the Air Force, elsewhere in the Department of Defense (DoD), and within many other potential commercial applications. This has led to the current situation where a version of the NOTAMs technology is being installed at the National Geospatial-Intelligence Agency (NGA), and another descendant of the technology is being developed as part of the Joint Mission Planning System (JMPS) Global Planning Common Component (GPCC). Some of these efforts were supported by extensions to the initial AFRL NOTAMs contract, while others have resulted in sub-contracts under the JMPS program. We include a brief history of this progression.

NOTAMs/GAMAT linkage

During the first six-months of the contract, after initial work on the parsing system and knowledge representation, BBN realized that there was a potential for providing the AF with a much more valuable product by integrating technologies being developed for two different AFRL projects, both supporting AMC –

- This ISQ NOTAMs project, supported by AFRL/IFSA at Rome NY
- The Global Air Mobility Advanced Technology (GAMAT) Global Weather Management project supported by AFRL/HECS at Wright Patterson OH

[1] A major requirement of this project was that the resulting technology be as widely applicable as possible – it was not clear throughout most of the project what the transition path would be if the technology was successfully adapted, so we made a strong effort to build on the most open existing standards for providing information from the parser to other systems. In particular, we focused on an XML-based web-service standard, since this would allow the results of the parsing to be made available to other systems on different computers, written in any of a very wide variety of computer languages. Since we were generating a semantic representation of the results of parsing (a representation of the meaning of NOTAMs that could be understood and reasoned with by computers) we initially chose to use the most widely specified standard for such information. This was the DAML+OIL XML ontology language developed by combining the best features of government sponsored research languages DAML (the US Defense Advanced Research Projects Agency ontology language) and OIL (the Ontology Interchange Language defined by the European community). Luckily, at the time we started the project these two potentially competing standards had been merged. During the course of the project, the W3C (World Wide Web Consortium – the international industry consortium dedicated to building consensus around Web technologies, the de facto standards body for all web-based languages and services) took DAML+OIL and produced the broader OWL standard. By adhering to this standard, we hope to make the results of our parsing and interpretation of NOTAMs readily accessible to any application with a need for information about NOTAMs.

The GAMAT system was designed as a decision support and collaboration system to support interaction between flight managers and the weather shop at AMC. It retrieved information about current and planned AMC sorties, as well a wide variety of weather related information, and provided a way for FMs to see these sorties in a map-based display. Additionally, it provided computer agent-based systems to reason about the potential effects of weather on these sorties, and to provide automatic alerts when changing weather information indicated potential problems for flights. This system was designed using the Work-Centered Support System technology supported by AFRL/HE, and was already operational as a prototype within AMC.

These two systems were both under development by groups within the same BBN department, and the BBN program manager and technical director realized that the GAMAT system could be used to provide a good means to show some of the capabilities already developed in the ISQ NOTAMs system. Under a BBN Internal Research & Development (IR&D) effort the NOTAMs system was integrated with the GAMAT Global Weather Management system demonstrating the utility of a simple reasoning capability to tie NOTAMs to missions and alerting on flight safety or mission impacting issues. The resulting demonstration of linkage of the two systems was shown to the two AFRL program managers Edward DePalma (IFSA) PM for the IFM project and Sam Kuper (HECS) PM for the GAMAT project. The results were sufficiently interesting to lead to demonstrations of the combined system to AMC and other parts of the AF, and this led to a coordinated effort by the two projects and the two AFRL directorates (/IF and /HE) to provide a more robust demonstration.

The MAF-CAF demonstration and follow-on work (JEFX ’04)

This demonstration became a key part of the Hanscom AFB Electronic Systems Command (ESC) Mobility Air Forces-Combat Air Forces (MAF-CAF) Global Situation Awareness initiative, which was being proposed in January 2003. According to a summary of the AMC-Air Force Materiel Command (AFMC) Day briefing on Feb 6, written by Dr. Al Graf of ESC/GA: "Col Al Moseley, ESC/GA and Col Al Baker, AMC/DOR presented a summary of the initiative at AFMC-AMC Day briefing on 6 Feb. We received very positive feedback from AFMC/CC, ESC/CC, AMC/CV, and others in attendance. The MAF-CAF team received direct support for the demo from Gen Lyles (Commander, Air Force Materiel Command), who offered to personally brief this (and its concept) to Corona of that year. He also offered, based on some comments made by Lt Gen Baker, AMC/CV to introduce/sponsor this project into the STRATCOM CAF-MAF Working Group 14 Feb, as well as the MAF-CAF Conference in late March. Furthermore, he offered O&M funding to support the demo, and echoed LtGen Looney's (Commander, Electronic System Center) comment that we should engage AFC2ISRC soonest (Col Paul Curlette (AFC2ISRC Mobility Liaison) is working to set up briefings/discussions with MGen Behler and appropriate staff.)"

The net result of this was that much of our work in the first year was demonstrated as part of a very successful CAF-MAF interoperability demonstration at ESC and Bolling AFB.

This in turn led to a successful Engineering Change Proposal to extend the original contract to support the Global Conops Synchronization demonstration at JEFX 2004.

Further contract extensions

Support for NGA

The initial work done on the design of a DARPA Agent Markup Language (DAML) ontology for NOTAMs was presented at the DAML Principal Investigator (PI) meeting in mid-October 2002. The result of this presentation was an invitation to present our work at the Semantic Web for Military Users conference in April 2003. This led to a contact with David White of the National Imagery and Mapping Agency (NIMA) (now NGA) who indicated that he thought our work would be of substantial interest to the NGA Aeronautical group in St. Louis. He made a contact in that office, and we arranged to make a presentation to a group of mid-level managers from that office.

On July 22, 2003 we presented a two hour briefing and discussion on the ISQ NOTAMs work to seven senior members from the Saint Louis facility of NIMA, office including Lewin M. "Skip" Ellis, Deputy Chief, Aeronautical Business Office. Also present was Greg Padula of AMC representing the project at the behest of Edward DePalma of AFRL.

This was followed by a presentation of our work to several Senior Executive Service (SES) level personnel, including Lynn Puetz, SES, Division Chief of NGA PN, Tom Bowes, deputy Division Chief, Chuck McGaugh, SIS who supports all the divisions in NIMA as a senior-level technologist, providing valued advice and opinions on new technologies and their relevance to NGA. This meeting was also attended by the AFRL Mobility ATD lead Edward DePalma (IFSA) and his AFRL branch tech advisor Dan Fayette (IFSA). The net result of this meeting was a decision by NGA to initially explore the use of ISQ NOTAMs technology in support of the NGA Aeronautical division, and to later provide a prototype operational capability for supporting the operations of the NGA Vertical Obstructions operation, both of which were accomplished by funding provided through the NOTAMs contract in support of an extension to the original contract providing effort to:

- Investigate NGA's Aeronautical Safety Division's NOTAMs practices and policies to determine any required upgrades to the NOTAMs ontology and system.
- Design, develop and incorporate into the NOTAMs ontology or system those upgrades mutually agreed to by the government and the contractor.

Install and support the upgraded version from above at a NGA location to be mutually agreed to by the government and the contractor for test, feedback, modification and reinstall purposes.

Exploratory technical efforts:

The contract was further extended to support the following exploratory technical efforts:

1) Knowledge representation development:
   - Extend the NOTAMs ontology to describe a set of critical resources/facilities/capabilities reported on by NOTAMs and the changes

and impacts on those resources due to the information contained within NOTAMs.

- Populate a knowledge base represented in terms of the above resource ontology for a critical set of resources based on available government and/or commercial data sources to create a specific instance knowledge base. Develop automated tools to populate and update the resource knowledge base.
- Develop tools to modify/update the resource knowledge base based on Web Ontology Language (OWL)-annotated NOTAMs.

2) Intelligent Access/Retrieval Query Mechanism

- Design an intelligent (inference-based) mechanism to permit other systems to access and retrieve task-focused resource and NOTAMs knowledge from the expanded knowledge base.

Develop prototype intelligent access and retrieval tools to demonstrate the mechanism designed above.

Methods, Assumptions, and Procedures

Limitations on technology imposed by input data problems and air safety considerations

As the project developed it became clear that:

- It would be possible to effectively extend and apply existing natural language and knowledge representation techniques to extract much of the critical information content for a large class of NOTAMs.
- The breadth of material covered in NOTAMs was much broader than initially expected, and the actual NOTAM text was full of human errors ranging from misspellings, to mangled grammar, to clearly incorrect specifications of changes in the aeronautical environment.

This led to an important caveat, accepted by the government as part of requirements document for the system to be produced:

> ISQ NOTAMs is a prototype system. It is not designed to be placed in operational use, but is intended to demonstrate the capabilities of current natural language processing and knowledge representation in the context of future AMC systems. The goal of ISQ NOTAMs is to increase the ability to automate the overall NOTAM distribution and decision making system, without compromising safety. The ISQ NOTAMs system will never change the content of a NOTAM, but will only add additional machine understandable annotations to a record describing the NOTAM. ***Systems that make use of the output of ISQ NOTAMs should exercise great care in filtering out NOTAMs based on the contents of annotations*** – perhaps only using issuing location and official time stamps for such filters. All other ***operations should be in the form of highlighting and organizing sets of NOTAMs*** to make it easier for planners, FMs and flight crews to quickly find the relevant critical NOTAMs for each phase of planning, monitoring and execution of a mission.
>
> **Because of the uncontrolled nature of the NOTAM text, and the likelihood that new reportable situations and variant ways of reporting such situations (as well as human error in entering NOTAMs) we do not expect that fully automated annotation systems will be feasible in the near term. Thus, the initial output of the ISQ NOTAMs must be reviewed for possible error. A human will be incorporated in the annotation loop, with software interfaces designed to substantially reduce the cost of such human supervisory control in the annotation process**

.While extensions and follow-ons to the NOTAMs contract have included producing initial operational capabilities as part of the JMPS system, it is important to note that the spirit of this caveat still holds. In the foreseeable future, no fully automated system will be able to extract information from all NOTAMs, nor will such a system be able to produce completely error-free results as long as the input NOTAM stream contains as

much dirty data as has been seen in the past several years of monitoring and parsing this input. Thus any operational system that uses this technology must be designed to use it in such a way as to improve the operation of the existing human-centered approach to finding NOTAMs relevant to given missions, never reducing or modifying the information currently presented to flight managers and aircrews, but primarily focusing on improving the situational awareness and effectiveness of flight managers and aircrews by highlighting critical information contained in NOTAMs. ***The goal of the resulting systems must be to increase ability to automate parts of the NOTAMs utilization process, without compromising safety – it must keep a human in the loop, and the human must be responsible for all flight safety decisions.***

As this program proceeded we learned many things that suggest profitable future areas of research and development for the Air Force. The ISQ NOTAMs project is just the tip of the iceberg in what can be done by appropriate application of parsing and knowledge representation problems to Air Force problems. The initial statement of work of this project indicated that the resulting system would parse and extract a limited number of critical pieces of information content from NOTAMs – the final result was much broader than initially conceived. However, it has become clear as we reviewed the results in parsing over three million NOTAMS, that there are important pieces of information that would be of value to the Air Force and others that could be extracted from NOTAMs, and that the accuracy and robustness of the output of the system can be improved. There are both incremental changes and major extensions that could (and should) be applied to this and related problems. There are changes and extensions to the grammar used by the parser that would make significant improvements in coverage (types of information extracted), accuracy and robustness (resistance to common and rare errors found in NOTAMS).

In terms of incremental changes, we estimate that six to twelve person months of effort on the grammar should cut in half the gaps in coverage and error rate in parsing. This effort would be enhanced by supporting active participation of domain experts (pilots, flight managers) in helping the computer scientists understand the content of NOTAMs. Experience has shown that while the majority of NOTAMs are readily understandable after background reading, there are a surprising number of NOTAMs that leave the developers scratching their heads and searching for information sources to explain them, and the ability to quickly get authoritative interpretations of these NOTAMs would substantially increase productivity.

Additionally, there is an ongoing effort by EUROCONTROL and the FAA (and more recently ICAO) to develop XNOTAM which is a standardized XML format for issuing machine-interpretable NOTAMs. The definition of XNOTAM is now scheduled to be produced in 2007. The utility of the current ISQ NOTAMs capability would be increased by making sure that its OWL representation can be readily inter-translated with the XNOTAM notation, so that systems can make use of both types of information. This could be achieved by retrofitting an XNOTAM based tag space to the ISQ NOTAMs system, and if possible by supporting collaboration to make the existing OWL NOTAMs part of the design for XNOTAMs.

Larger scale changes that are obvious at this point are the ability to interpret the use of two dimensional (tabular) formatting in NOTAMs, and the incorporation of reasoning based on aeronautical knowledge basis such as DAFIF (the Digital Aeronautical Flight Information File) directly into the parsing process.

Tabular formats are not typically addressed by computational linguistic systems, and the original NOTAMs source provided to us was discovered (at the end of the project) to have automatically replaced all line-feeds with spaces, thus totally destroying the two dimensional formatting carefully inserted by human NOTAM entry. When the original NOTAM format was provided to us as part of the FAA support of the JMPS program, it became clear how much information could be obtained from this formatting, and how many seemingly intractable parsing problems (phrases whose meaning were not readily interpretable from the linear sequence of words) were substantially clarified (to the human eye, at least) by restoring the formatting. There is very little currently available technology to deal with parsing such two dimensional formats, and both research and development is needed – the net result would be substantially improved parsing of the 10-20% of NOTAMs that use such formatting in a critical manner.

There are many cases of ambiguity and error in NOTAMs that are typically resolved by human readers (e.g. pilots) using commonsense reasoning. Thus, for example, “this NOTAM was issued by Germany, and there is a latitude/longitude pair in the middle of an airspace description that is in Zimbabwe – this is probably a typographical error”, “LEGAL is the name of a waypoint, but in the context of the phrase LEGAL REQUIREMENTS it is probably not a reference to that waypoint”, or “this Belgian NOTAM mentions a navaid designator in use in the US, Australia and Belgium – the most likely interpretation is the Belgian navaid. Some rudimentary forms of this reasoning are incorporated in the current system as post-processes to parsing and they were added after the fact to solve particular problems. Sometimes this post-processing is too late – the parser was forced to make a decision, and alternative interpretations are discarded within the parsing process, making it impossible to correct by later reasoning. A more thorough integration of reasoning early in the parsing process would seem to be the right approach to handling these problems (though other approaches should also be investigated).

Finally, although we have continually tried to assess the performance of the current system, and have developed many tools to do so, there is critical work to be done in the specification of formal performance requirements for such a system, in terms of accuracy and completeness of its parses and the resulting characterization of NOTAMs. As mentioned, the characteristics of NOTAMs as human entered text makes perfect parsing an unattainable goal – the critical issue is to determine how good is good enough (what can be done to reduce the workload of flight personnel, and increase their situational awareness while increasing, or at least not compromising, flight safety).

Design requirements

As a result of discussions with AFRL and AMC personnel, it was decided that there were a number of requirements that had to be met by the resulting system. It must:

- Increase the ability to automate the NOTAMs process without compromising safety –
  - Must keep a human in the loop
  - Provide human supervisory control in the annotation process
- Provide machine ***understandable*** representations of selected NOTAM content to be used by other applications,
  - The appropriate type of information to be extracted from NOTAMs depends on the planned downstream applications
- Be a reusable and modular component that can be readily integrated into a number of potential systems
  - Use current web technologies to build a component which can be readily integrated into a NOTAM distribution system (not build a distribution system)

Operate within the constraints of the existing AF and DINS established NOTAMs system. It must obtain NOTAMs from an official source, and it is not allowed to modify the original NOTAMs.

Overall architecture

In order to satisfy these design requirements, we developed the following architecture, which has been maintained with minor variations up until the time we started direct implementation of a JMPS version of the system. The system architecture designed to meet these requirements is shown in Figure 6.

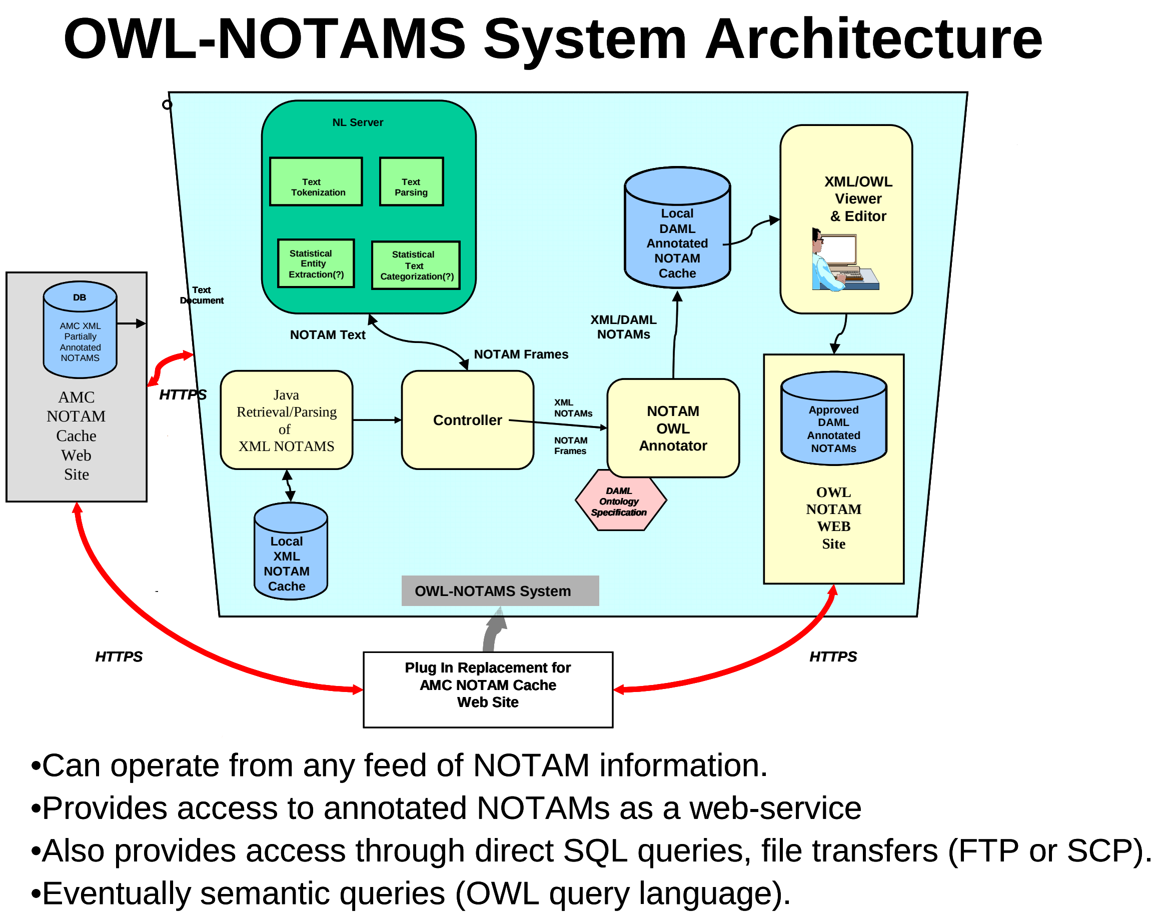

Figure 6: The OWL-NOTAMS System Architecture

It was discovered early in the project that there was an existing Extensible Markup Language (XML) formatted web-accessible official source of NOTAMs being used by AMC – the AMC NOTAM cache. The fact that the AMC NOTAM cache used XML and web services made the architectural decision straightforward. We had already intended to represent the information content of NOTAMs in DAML+OIL, an XML ontology sub-language. We also planned to provide this information in the form of annotations attached to the original NOTAMs. Since it is technically simple to add new XML formatted fields to an existing XML document, we decided that in order to provide maximum flexibility, the system was designed as a middleware XML web-based process. The initial system would obtain each NOTAM from the AMC NOTAM cache, apply appropriate natural language techniques to extract critical information from the NOTAM, represent that information in XML (as a DAML+OIL annotation) and produce an extended form of the original NOTAM, containing all the original XML fields, plus one new field that held the DAML+OIL annotation. Additionally, to support continued development and testing of the system as the set of active NOTAMs changed over time, we would maintain a complete local store of NOTAMs, mirroring the history of NOTAMs

available from the AMC cache. We would also provide a web-interface that was identical in form to the AMC NOTAM cache, so that:

- any legacy system which could retrieve NOTAMs from the cache would be able to access the ISQ NOTAM cache and use the output as a replacement for the AMC cache simply by ignoring the added field
- any system that wished to make use of the new information provided the annotated NOTAMs could retrieve them in the same way as a legacy system

Within the first month of the project we had implemented a system to pull all NOTAMs from the AMC cache and populate an ever-growing local store of NOTAMs. We have used this store over the life of the project, testing new versions of our system not only on the current active NOTAMs, but also on large sets of historical NOTAMs. To date we have processed over 4,000,000 NOTAMs.

Key technical problems addressed by the project

In order to understand the problems to be addressed by this project we examine the difficulties faced by two suggested alternative approaches to the problem of alerting FMs to critical NOTAMs.

Option 1 - Why not simply use Q-codes?

The first approach makes use of Q-codes, five-character internationally standardized codes that are intended to represent the critical information content of NOTAMS. To quote the appendix of Federal Aviation Order 7930.2, Notices to Airmen, Q-codes are defined as follows:

> **a**. A NOTAM code group contains five letters. The first letter is always the letter "Q" to indicate a code abbreviation for use in the composition of NOTAMs.
>
> **b**. The second and third letters identify the subject being reported. (See Second and Third Letter Decode Tables in section 0).
>
> **c**. The fourth and fifth letters identify the status of operation of the subject being reported. (See Fourth and Fifth Letter Decode Tables in section 0).

Thus, a NOTAM containing the Q-code QMRLC can be decoded as meaning "runway closed" based on Q (indicating a Q-code) M (movement area) R (runway) LC (closed).

The majority of international NOTAMs and US military NOTAMs contain Q-codes. Unfortunately Q-codes do not provide an adequate solution to the problem posed by AFRL and AMC, because:

- Not all NOTAMs contain Q-codes
    - In particular, US domestic NOTAMs almost never contain Q-codes
- Q-codes provide incomplete information for decision making, e.g.
    - Given a QMRLC NOTAM, it is critical to know what runway is actually closed
    - For a QRACA NOTAM, it is critical to know the geo-spatial bounds of the area reserved
    - For a QP NOTAM it is critical to know which procedure is being affected

- Many Q-codes that show up in actual NOTAMs are incomplete or inaccurate
    - In a large sample of US military and international NOTAMS taken early in the ISQ NOTAMs project, approximately 1/3 had QXXXX as the Q-code – this wildcard Q-code has no explicit meaning, and is intended to be used only for cases not covered by other Q-codes. In fact, the text of a very large number of the QXXXX cases is completely consistent with a more informative Q-code

Thus, a system built on Q-codes will not be able to correctly categorize a very large number of NOTAMS, and will be unable to obtain critical information from much of the remainder

Option 2 - Why not use keyword search on the text block?

The IMT system attempts to aid FMs in discovering critical NOTAMs by doing simple keyword search in the NOTAM text block. Unfortunately, not only is the method unable to obtain critical information such as the boundaries of special use airspace, but it is also reported by FMs to produce an unacceptably high number of “false alarms” (some FMs have said that using this feature has a tendency to “turn the entire NOTAM screen red”). Why is this? Consider a simple case – FMs must be aware of all runway closures that affect aerodromes of current interest, as well as all closures of the aerodromes themselves. The text string **CLOSED**[2] (and a few variants such as **CLSD**) **is** a common indicator for runway and airport closures. Using this as a search term provides many false alarms because many other things can be closed as shown in the following NOTAMs:

ZGNN|NANNING/WUXU|A0484/04 … E) TWY 4 CLSD
MMCS|CIUDAD JUAREZ|A1355/04 … E) TURNING BAY THR RWY 03
MROC|ALAJUELA/JUAN SANTAMARIA INTL.|A0454/04 … E) ACFT STAND NR 09 CLSD
EPWW|WARSZAWA/ACC|A2257/04 … E) ATS ROUTE R236 BTN VAVEL-LENOV FM FL065 UP TO FL085 CLSD

Even slightly more complex patterns do not function well, so the pattern ***RWY…CLSD*** will pick up the following NOTAM:

LIPH|TREVISO/S.ANGELO|M1310/04 … E) 1ST AND 3RD MIL TWY RIGHT SIDE RWY07 CLSD

In order to go beyond these two approaches we needed to make the critical information contained in the NOTAM text block (already a “machine readable” form) into something that a machine could reason on and display in various forms (a “machine understandable” representation). Graphically, using an annotated screen shot from a running ISQ NOTAMs system, our goal was to support the following process:

[2] To give a slight idea of the actual types of variations we have seen in NOTAMs, the ways that closure can be represented in NOTAM text includes: CLSD, CLOSED, DCMSND, CLOSURE, DECOMMISSIONED, WILL BE CLOSED, IS CLOSED, DEACTIVATED, ARE CLOSED, DCMSN, IS CLSD, REMAIN CLSD, WITHDRAWN FROM SERVICE, COMPLETELY WITHDRAWN FROM SERVICE, CLOSD, FERME, FERMEE, WILL BE WITHDRAWN FROM SERVICE, CLS, CLSDS, CLSED, CLOSING, COLSED, FERMETURE, DESACTIVADO.

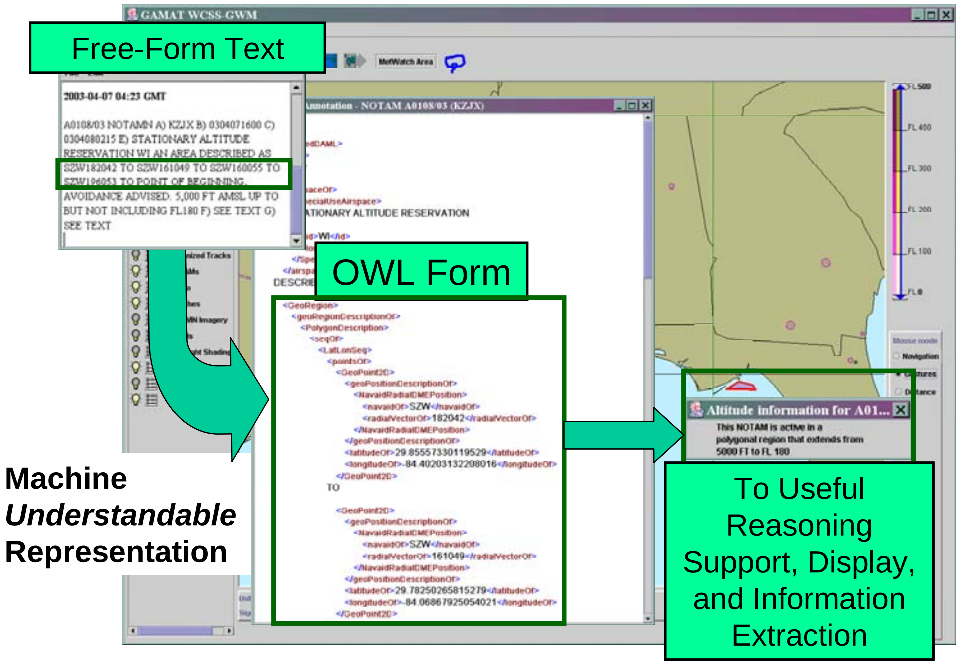

Figure 7: The process of bringing free-form NOTAMs text to machine-understandable representation

This posed two problems:

Problem 1: We needed to represent the complex real-world structure of the critical information expressed by NOTAMs

Solution: Knowledge Representation Technology (in particular, semantic web technology)

Problem 2: We needed to recognize and interpret complex structured patterns in NOTAM text that encoded the critical information

Solution: Language Processing (Parsing technology)

Parsing

The original concept for the parsing engine of the ISQ NOTAMs project was to build on BBN's substantial experience in building natural language parsers, particularly leveraging recent work on high accuracy statistical parsers for English. This seemed reasonable since documentation on NOTAMs indicated that by ICAO standards, NOTAMs were supposed to be issued in English, the standard international language for flight safety. In the early stages of the project, we performed an analysis of tens of thousands of actual NOTAMs and discovered that the "English" of NOTAMs was not the same as the English we had developed tools to parse. We discovered that NOTAMs text was not uniform but in fact had quite a range.

From simple but cryptic:

- ***A) CYYT B) 0302141922 C) 0302151530 E) ILS GP 29 U/S***
- ***MIA|MIAMI INTL|MIA 02/140 MIA 30 ILS OTS WEF 0502241000***
- ***22 ILS OM OTS WEF 0302041800-0302042200***
- ***TOWER 1099 (499 AGL) 11 S LGTS OTS TIL 0302251611***
- ***17L/35R PTCHY THN IR/SLR ON EDGES WEF 0302182328***

To somewhat more complex:

- ***ZJX|JACKSONVILLE (ARTCC),FL.|CARF 03/009 ZJX STATIONARY ALTITUDE RESERVATION WITHIN AN AREA DESCRIBED AS SZW182042 TO SZW161049 TO SZW160055 TO SZW196053 TO POINT OF BEGINNING. AVOIDANCE ADVISED. 5000-17999 WEF 0503021330-0503030145***

To legalistic and complex:

- ***LGGG|ATHINAI (ACC,FIC,FIR,UIR)|A2379/04 NOTAMN Q) LGGG/QWELW/IV/BO/W/000/999 A) LGGG PART 1 OF 2 B) 0501030500 C) 0503311300 E) NAVIGATIONAL WARNING TO ALL CONCERNED: THIS NOTAM IS ISSUED TO STATE THAT THE TURKISH NOTAM A3019/04 LTAAYNYX IS NULL AND VOID SINCE IT REFERS TO TURKISH MILITARY ACTIVITIES WITHIN ATHINAI FIR WHERE THE ONLY COMPETENT AUTHORITY TO PROMULGATE NOTAMS IN ACCORDANCE WITH ICAO RULES AND REGULATIONS IS THE HELLENIC CIVIL AVIATION AUTHORITY THROUGH ITS APPROPRIATE AIS UNIT AND THE ONLY RESPONSIBLE AUTHORITY FOR THE SAFETY OF THE AIR TRAFFIC IS THE HELLENIC CAA THROUGH THE ATS UNITS. FURTHERMNORE GREECE HAS ALREADY ADVISED TURKEY BY COORDINATION MESSAGES 271230 AND 291236 LGACYAYC THAT THE MENTIONED EXERCISE AREA DEFINED BY COORDINATES 401630N253900E, 401800N253000E, 403500N245800E, 401100N243300E, 400900N244500E, 402000N245600E, 400700N253300E OVERLAPS AREA OF NATIONAL SOVEREIGNTY OF GREECE AND CONSEQUENTLY IT IS NOT AVAILABLE. THE SAID AREA ALSO OVERLAPS PART OF LIMNOS TMA.***

Further analysis showed demonstrated that NOTAM text was in fact **not English, but a highly specialized sub-language with special vocabulary and syntax that is characterized by high variability, embedding[3], a lack of recursion, and few constraints on word order.** In fact, NOTAMs seem to be closer to what linguists term a "pidgin" than a natural language – this is not surprising, since the context in which NOTAMs are issued is a classical context for the formation of a pidgin. (A Pidgin, or contact language, is the name given to any language created, usually spontaneously, out of a mixture of other languages as a means of communication between speakers of different tongues.) NOTAMs are produced in a primarily free text form by over 6,000 individual airfields and air traffic control centers in 160 countries around the world. Thus, NOTAMs represent an attempt at communication by a group of people who do not share a common native language (given that they are issued by 160 countries).

In addition NOTAM vocabulary is a highly technical and abbreviated variant of English, for the most part, with substantial numbers of abbreviations and jargon-like phrases (as well as 1-2% of French and Spanish NOTAMs, and even the odd Czechoslovakian NOTAM). Additionally, even when considered as a pidgin, NOTAMs contain plentiful misspellings, many obvious errors, and wide variation in ways of expressing even very common content such as time and duration phrases, locations and even standard safety equipment. Despite attempts at standardization both nationally and internationally there is multiple national standards for NOTAM report formats, and such standards are commonly breached. The majority of NOTAMS are manually input, NOTAM text uses a highly abbreviated flight domain language; misspellings are common, sentences are fragmented, punctuation is applied haphazardly, and ambiguities and errors occur in many NOTAMs.

We initially planned on modifying BBN's trainable context free parsing system to handle NOTAMs, but it became clear that this approach had problems. Since NOTAM text was clearly so far from the type of English that the system had been trained for, we would not simply be adding to the training set and getting reasonable results. It would be necessary to provide hand-built annotation for a large body of NOTAMs. In the case of other natural languages, we have been able to do this at reasonable expense because it was usually possible to find native speakers of the language in the local college population, and to hire them to annotate a body of text. It was not at all clear what the equivalent would be for the international set of NOTAMs. Typically, most people who have learned to read NOTAMs are licensed pilots. At the very least, we would have to find a set of trained pilots to use for the annotation, and the cost would likely exceed our budget. Additionally, while such pilots might be able to understand NOTAMs so that they can fly safely, they would have to be trained themselves to understand the type of structures needed to annotate the NOTAMs. One additional

[3] Embedding, in this context, is the construction of phrases from smaller phrases such as PRECISION APPROACH LIGHTS RWY 27 OTS which is made up of "PRECISION APPROACH LIGHTS", "RWY 27" and "OTS" (out of service). Recursion is embedding in which the contained phrase is of the same type (though not identical) to the containing phrase, as in the English "the man who was seen talking to a young woman" in which "the man" and "young woman" are both noun phrases, and this can be extended to "the man who was seen talking to the young woman who was carrying a child who was giggling."

major factor appeared – speed of parsing. While the operational NOTAMs system would have moderate processing constraints (hundreds of NOTAMs/hour) the development phase would require very fast processing. It would be important to be able to understand the linguistic patterns in very large groups of NOTAMs (tens of thousands of NOTAMs). Additionally, when considered as "sentences" very many NOTAMs had extremely large numbers of words.

Existing natural language parsers could not parse the hundred or more tokens that make up a single NOTAM in under a second, and we needed to parse many NOTAMs per second.

In order to deal with these problems, and given that our goal was to extract critical information from NOTAMs, but not necessarily provide complete parses for them, we decided to look at approaches other than variants of context free parsing. The parsing approach and rule set we chose are targeted to the observed characteristics of the NOTAMs language.

NOTAMs text is:

- Specialized, complex but not recursive like more general natural languages such as English
- NOTAMs typically consist of sets of hierarchical phrases, with far fewer phrase order constraints than English.

After considering these features, and the need for high efficiency, we decided to use an approach which had been demonstrated to produce good results in a variety of information extraction problems. We built our parser as a ***cascade of finite state transducers.*** To quote a paper on the subject: "Finite-state cascades represent an attractive architecture for parsing unrestricted text. Deterministic parsers specified by finite-state cascades are fast and reliable. They can be extended at modest cost to construct parse trees with finite feature structures. Finally, such deterministic parsers do not necessarily involve trading off accuracy against speed---they may in fact be more accurate than exhaustive-search stochastic context free parsers." (Steven Abney. 1996. Partial parsing via finite-state cascades. In Workshop on Robust Parsing, 8th European Summer School in Logic, Language and Information, Prague, Czech Republic, pages 8--15.)

In order to pursue this approach we first experimented with an existing finite state cascade (GATE – a General Architecture for Text Engineering). This showed that the approach was feasible, but the GATE parser was far too slow for our purposes, and had serious restrictions on the types of semantic output. Thus, we developed the FIST (Finite State Transducer) system, an extremely efficient implementation of a cascaded finite state analyzer. FIST is implemented on top of Java, with the key recognition phase being done using a Java implementation of a finite state processor built on networks of hash-coded dispatch tables. The process of "semantic interpretation" of the resulting phrases is written in JScheme, which is a version of the Scheme programming language implemented in Java, and which provides efficient and perspicuous access to all aspects of programs written in Java, including all of the Java libraries. The FIST parser is FAST, and it can readily integrate large-scale specialized dictionaries (e.g. complete DAFIF special use airspace, navaid and waypoint data). Versions of FIST with an initial moderate size cascade (fifty rules) parsed 30 NOTAMs per second on a

standard desktop PC, and the most recent (and substantially more complex) version of the system with several hundred rules still parses more than 5 NOTAMs per second.

Ontology

As part of the project design we planned to represent the critical information content of each NOTAM as an XML annotation within the XML structure for the NOTAM. The goal was to use the most expressive standardized representation available. The decision was made to use an "ontological" language, and to choose such a language which was compatible with XML.

> An **ontology** is a data model that represents a domain and is used to reason about the objects in that domain and the relations between them. Ontologies are used in artificial intelligence, the semantic web, and software engineering as a form of knowledge representation about the world or some part of it.

At the start of the project the best choice of representation appeared to be the DAML+OIL standard established by a joint US/EU commission, based on the DARPA DAML language and the European OIL language.

Some early responses to our design decision raised the question as to why we used an ontology language, rather than using "straight XML." It is important to realize that DAML+OIL annotations are in fact well-formed XML – it is just that DAML+OIL has a well defined semantics, not simply a well-defined structured syntax. Another suggestion was to use a semantic extension of XML called the Resource Description Framework (RDF). In fact, DAML+OIL is an extension of (and compatible with) RDF. The distinctions between XML, RDF and DAML+OIL can be summarized as follows:

- XML is the universal format for structured documents and data on the Web, but:
    - [SGML and]XML are meta-language facilities for defining markup languages. [which] declare formal features for syntax, but have no mechanisms for formally expressing semantics. SGML parsers and XML processors do not know what is meant by the natural language labels (element type names, attribute names), nor what may be implied by the instance hierarchy; … In SGML and XML, semantics can be expressed only informally (*e.g.*, in comments). (http://xml.coverpages.org/semantics.html)
- RDF is a language written with XML syntax that adds the following features:
    - machine understandable semantics for metadata
    - At the core, RDF data consists of *nodes* and attached *attribute/value pairs*. Nodes can be any web resources (pages, servers, basically anything for which you can give a URI), even other instances of metadata. Attributes are named properties of the nodes, and their values are either *atomic* (text strings, numbers, etc.) or other resources or metadata instances. In short, this mechanism allows us to build *labeled directed graphs*.
- DAML+OIL extends RDF and provides a means to define ontologies with a formal semantics

- DAML+OIL combines the machine readability of XML, the standardization of RDF, and the expressive power of an ontological language

Early in the project we developed and published specifications for a DAML+OIL ontology which we used to capture the information content of NOTAMs. This included representations of all critical capabilities and infra-structure relevant to high-value NOTAMs

- Aviation specific environment - Aerodromes, runways, navaids, lights, routes, fuel
- Underlying knowledge in uniform fashion – temporal, spatial (geographic) structures
- Aviation requirements, situations, policies - landing minima, RNP, MNP, closures, failures,

We were forced to develop and/or extend DAML+OIL representations for a number of areas which had not been standardized at the time the project began.

- Temporal ontology extends standard DAML Time ontology
- We developed a spatial/geographic ontology that was presented as a draft to the DAML Spatial Ontology Working Group

Several technical issues were addressed and resolved in this work. One was the fact that NOTAMs often contained measurements such as altitudes, runway lengths, distances, relative positions, and it was necessary to develop a general representation of measurements that allowed for variations in units of measurement (e.g. feet vs. meters vs. miles) and measurement origins (altitude **above sea level** vs. altitude ***above ground level***).

The technique used to deal with this is to separate out the notion of the "description" of a quantity or measurement from the quantity of measurement itself. As an example, consider that one single particular length might be expressed in two different ways as "6000 feet" or "1 nautical mile." We developed a representation that separated out the description used in the text from the underlying object. This strategy, originally applied to measurements, turned out to be useful for other things. In particular, there are several ways commonly used to express locations in NOTAMs – radial fixes from navaids, GPS coordinates, waypoint designators, etc. In some NOTAMs multiple descriptions were given of the same point on the ground (commonly navaid fixes and GPS coordinates). By describing all of these as instances of a common GeoPoint2D with multiple descriptions, we were able to capture the content of the NOTAM in a way that made it easy to perform reasoning. Another problem we discovered in this effort was the fact that many of the geographic regions referred to in NOTAMs involved specification of ***sequences***[4] of geographic locations (GeoPoint2Ds). Representation of sequences is an area where the DAML+OIL representation makes no commitment, and

[4] The variety of ways that such sequences are represented in NOTAMs is quite amazing. Not only have we discovered over 60 different patterns for specifying a single position consisting of a latitude and longitude, we have discovered hundreds of variations in the way that these specifications are combined together to form a sequence, and the ways that they are combined with names of towns, waypoints, navaids, etc. Some examples of this are:
"341028N690252E, 340710N685822E, 341012N685613E, 341359N685644E, 341432N690118E, 341359N690355E"
"(PRIMOSTEN) - 435848N 0155818E (KISTANJE) - 441030N 0153342E (NOVIGRAD) - 440630N 0152048E "
"501137N0163347E-500839N0162511E-500632N0162156E -495215N0161848E-495039N0154230E-494607N0155058E-"
"FROM STEFF NCRP(N39 57 W75 15) TO SAVVY NCRP (N39 48 W75 27) TO DPONT NCRP (N39 41 W75 36)"

we were forced to make use of the sequential nature of XML lists. We have proposed this strategy to the DAML+OIL community. As the project progressed we extended the ontology and this extended our ability to represent more of the critical NOTAM content. We also made an effort to keep up with the rapidly evolving standards for representation. On the base language side in February 2004, DAML+OIL was succeeded by the W3C standard Web Ontology Language (OWL). OWL is a direct descendant of DAML+OIL, and we were able to revise our DAML+OIL ontology into an OWL ontology with relatively little effort. At the same time, we became aware of the existing EUROCONTROL (European Organisation for the Safety of Air Navigation) effort on developing the Aeronautical Information Exchange Model (AIXM), a standardized XML representation of airspace information, designed to allow sharing of information among the various national aviation agencies in the European Union (EU). We were informed that EUROCONTROL was in the process of designing an extension of AIXM to represent the content of NOTAMs, called XNOTAM. At the same time we found that the FAA and NGA in the US had come to an agreement with EUROCONTROL to support the developing AIXM and XNOTAM standards. Through our work at NGA and our contacts with the FAA, we were invited to present our work to the EUROCONTROL AIXM Control Board, and we have modified our representation to make it more compatible with the directions that appeared to likely for XNOTAMs. At this point XNOTAM is still in the development stage, as indicated by the EUROCONTROL web page which includes the following paragraph:

> **“XNOTAM” in 2007.** The main objective is to bring the temporality to aeronautical information be used in airborne or ground-based systems, to augment and in time replace the venerable NOTAM. The XNOTAM concept will reflect the investments already made in information systems and in consequence will be fully (backward) compatible with the current NOTAM system.

With the close-out of the initial AFRL ISQ NOTAMs project, harmonization of the OWL NOTAM representation with XNOTAM will be carried on under the various JMPS-related follow-ons to this project. Currently, BBN is engaged in transition efforts with AMC through integration efforts with JMPS via the Global Planning Common Component (GPCC) and Tanker, Airlift, Special Missions (TASM) delivery order contracts with Hanscom ESC. In both cases, BBN is participating as a subcontractor to TYBRIN Corporation, the system integrator. GPCC is scheduled to field in April 2007, with the first TASM spiral fielding in 2008.

Results and Discussion

Under the ISQ NOTAMs contract BBN has developed an OWL ontology capable of representing a substantial portion of the content of NOTAMs and supporting retrieval and reasoning on those NOTAMs. This OWL ontology allows us to represent and reason about the status of runways, taxiways, ground/air communications, navaids, and other aerodrome capabilities. This includes runway closures, snow and ice conditions, and quiet hours and aerodrome-wide usage restrictions.

While it is important to be able to represent such status and constraints in a formal and standardized XML-based language such as OWL, this would be useless if we were not able to map the often cryptic, highly varied text of NOTAMs produced all over the world into this standard representation. Under the ISQ NOTAMs project we have developed natural language parsing and understanding techniques to produce a new generation of tools that can efficiently map the content of NOTAMs into the ontology. It is abundantly clear that NOTAMs were not written in a “dialect of English”, but rather formed their own separate sub-language with highly specialized vocabulary and abbreviations, local syntax quite different than English, and a high-level structure more like a linguistic “pidgin”[5]. Perhaps more important is that there are a large number of misspellings, variant abbreviations, and other errors. Presence of white space between words is often optional, and the choice of separating punctuation is idiosyncratic. This, plus the existence of a wide variety of low-frequency “explanatory text” of highly variable structure makes it inappropriate to attempt complete or top-down parsing to extract meaning. The most effective technique for parsing in this case is a cascade of finite state transducers. To implement this process we have developed a new, highly efficient, Java-based finite state transducer language, called FIST, which can integrate large vocabulary phrasal lexicons (including a 60,000 phrase lexicon derived from the Digital Aeronautical Flight Information File (DAFIF) waypoint and navaid tables). We believe that FIST may prove useful in a number of other AF message parsing problems such a

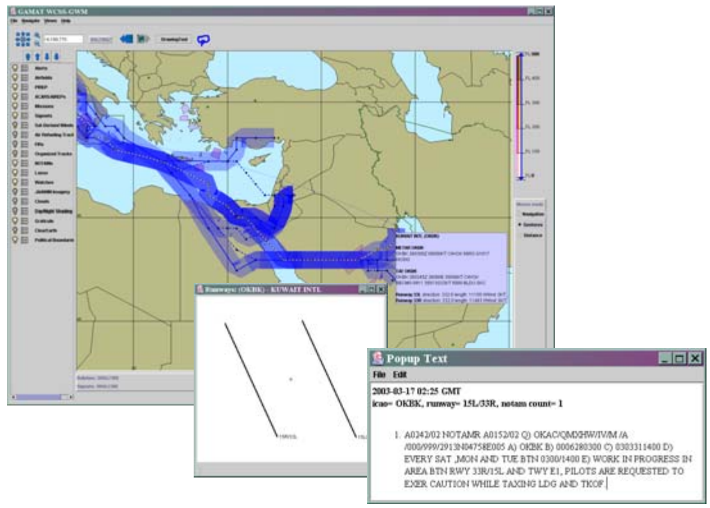

Figure 8: Screenshot of graphically represented NOTAMs

[5] A simplified language derived from two or more languages is called a **pidgin**. It is a contact language developed and used by people who do not share a common language in a given geographical area. …the structure is very simplistic.http://logos.uoregon.edu/explore/socioling/pidgin.html

METARs (Meteorological Aviation Reports), PIREPs (Pilot Reports), etc. FIST is capable of parsing over 15,000 NOTAMs an hour on a standard desktop or laptop PC. As shown above, these tools make it possible to break down the often large set of NOTAMs for a given aerodrome, and assign them to different resources within the aerodrome, including individual runways, taxiways, lighting, arresting systems and navaids.

Parsing and representation of three-dimensional geographical regions

One of the more difficult representational and parsing problems we have made substantial progress on is the representation of complex three dimensional airspace regions, and the ability to map NOTAM text into OWL annotations sufficient to draw maps of affected airspace. These include both polygonal and circular regions, as well as complex corridors. Some examples of the result of this parsing and interpretation are shown below. All pictures are from demonstrable software running with a database of over 250000 NOTAMs, including approximately 30,000 active NOTAMs obtained from the AMC NOTAM cache, and missions obtained from the Global Decision Support System (GDSS).

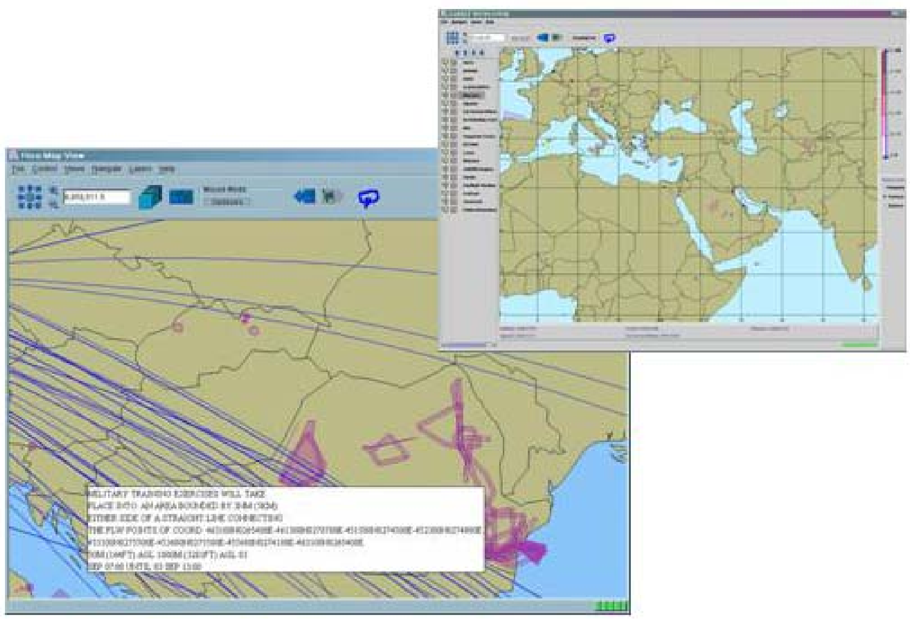

Figure 9: Graphically represented NOTAMs along with free-text in the HISA Map View

BBN also demonstrated that it is possible to use “corporate knowledge sources” such as DAFIF to increase the vocabulary of the ISQ NOTAMs parsing system, and also to perform certain types of reasoning about the objects mentioned in the NOTAMs (e.g. mapping implicit references to geographic locations given by navaid fixes to explicit latitude/longitude points)

To demonstrate the potential of the OWL annotation, as well as to test the generality of the web-based interface to ISQ NOTAMs, we integrated the ISQ NOTAMs system with two WCSS-based situation awareness and decision support systems (HISA and GAMAT) developed under AFRL/HE support, which are currently being evaluated at AMC

These integrations demonstrate an initial set of reasoning and display capabilities made possible by semantic representation. In these pictures we see the screens generated by a user who has highlighted a particular mission from

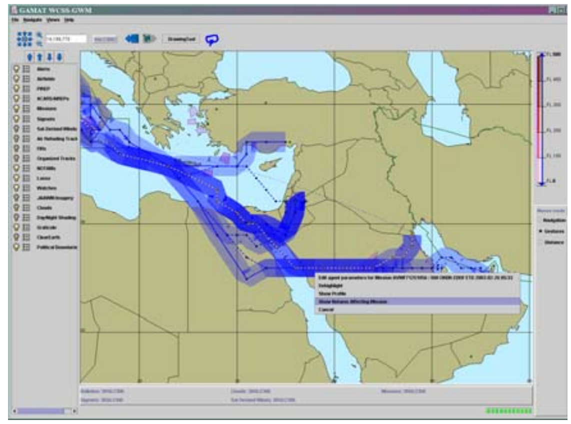

Figure 10: NOTAMs displayed in GAMAT

Kuwait International Airport to Frankfurt Main, and then requests the system to find the NOTAMs which pertain to that flight. The system finds the NOTAMs that affect the airports involved at the time of the mission, and (as indicated in previous pictures) shows the different types of NOTAMs at each port. In addition, the system performs three dimensional airspace calculations to determine that there is a NOTAM describing activities in a region crossed by the flight, and highlights the region on the map

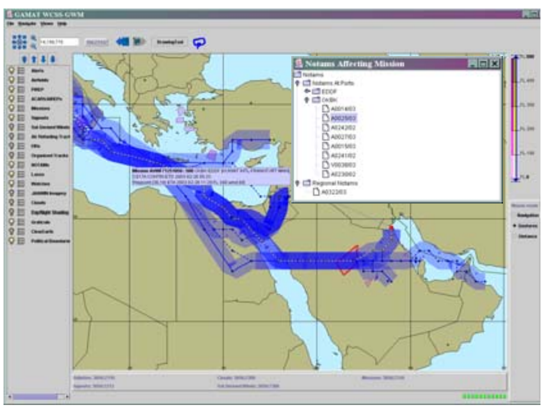

Figure 11: Tree view of NOTAMs in GAMAT

We have demonstrated that:

Mapping regions facilitates <u>interpretation</u> by pilots, and makes it easier to detect <u>anomalies</u>

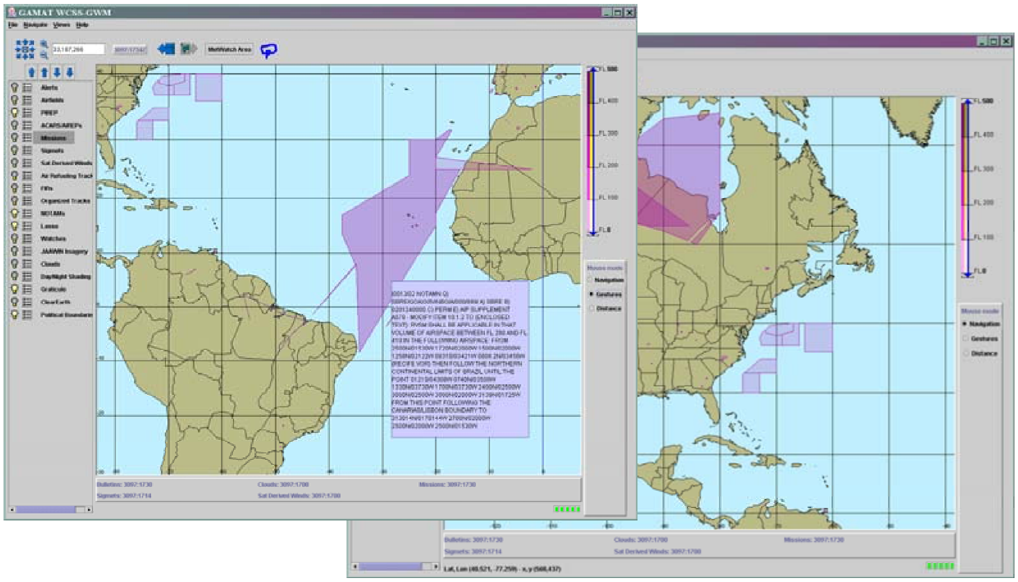

Figure 12: NOTAMs displayed in GAMAT

Building a model of the airspace <u>facilities</u>, <u>procedures</u> and <u>capabilities</u>

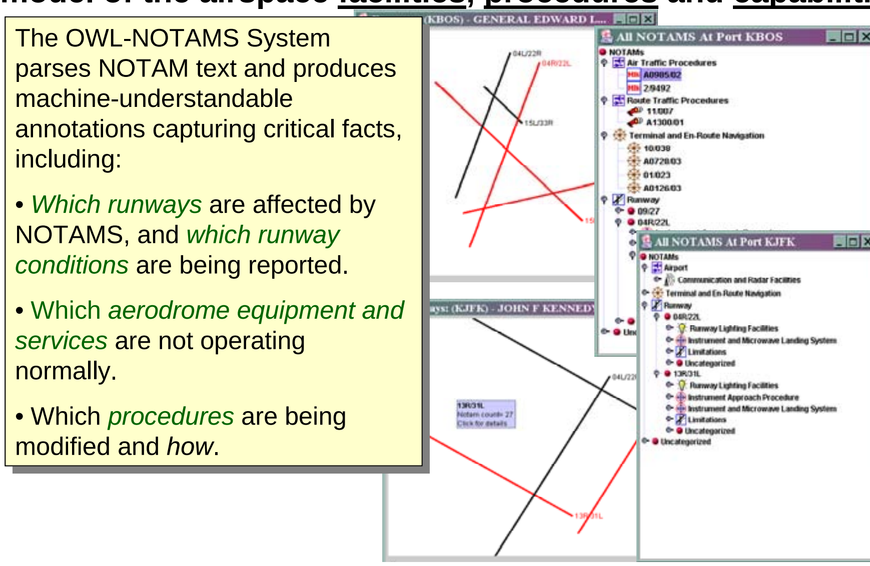

Figure 13: Port NOTAMs on display for KBOS (Boston Logan Airport)

The diagram above shows some displays that were produced as part of the ISQ NOTAMS/GAMAT GWS integration experiment. These displays formed the basis for the design of parts of the NOTAMs component of the Joint Mission Planning System (JMPS). On the displays above we make use of the fact that the parser can determine which runways are affected by NOTAMs, and combine that with information retrieved from NGA's DAFIF database to draw "live diagrams" of any airfield, where runways affected by current NOTAMs are highlighted, and in which the user can click on a highlighted runway to find out all NOTAMs that mention that runway. Additionally, for each airfield that has issued NOTAMs, the user can bring up a tree-like display that

breaks down the NOTAMs by category (see description below). A single NOTAM may appear more than once in this list, because the parser may assign a NOTAM to more than one category – for example, a NOTAM may affect a runway, it may mention a new vertical obstruction that is the cause of the issue, and may specify a change to procedures for using that runway. For any runway shown in the display, the user get a color-coded highlighted version of the NOTAM indicating the key phrases found by the parser that led it to categorize the NOTAM – the runways, the lighting systems, the procedures, etc. The user may also see the entire parse of the NOTAM in a tree structured form, though this is primarily of use for the ISQ NOTAMs system developers, and would not be expected to be valuable to pilots or flight managers.

OWL NOTAMs representation makes it possible to reason about the impact of airspace NOTAMs on particular planned (executing) flights. The OWL NOTAMs representation contains complete boundary information for special use airspaces described (announced or modified) by NOTAM, including Danger Areas, Warning Areas, Live Firing Areas, Glider activity, Parachute Jumping activity, etc. The parser also determines the vertical bounds of the airspace described, as well as the time periods of activity. This enables a reasoning engine to determine whether a given flight plan is likely to fly through or near the geographic region specified by the NOTAM. Additionally, it allows the reasoner to determine those cases where the NOTAM is unlikely to affect the aircraft, even though the path crosses the region, because the aircraft will be sufficiently above (or occasionally below) the region, or will be crossing the region at a time when it is not active.

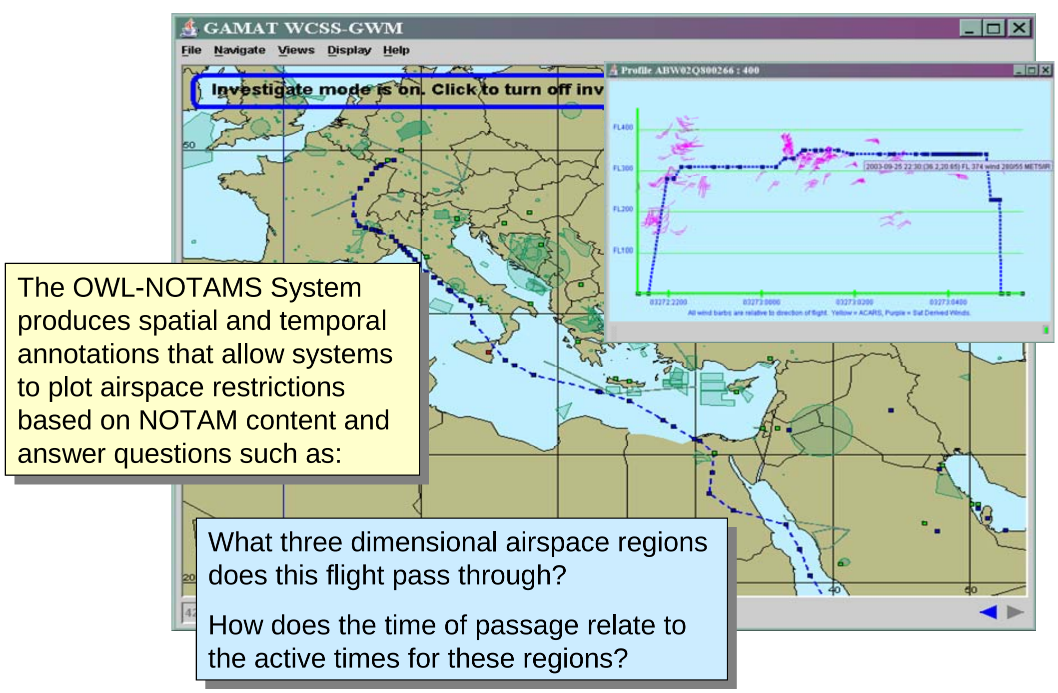

Figure 14: Spatial and temporal annotations

Categorization of NOTAMs

In support of appropriate dissemination of NOTAMs we have developed a set of over one hundred categories that are appropriate for distinguishing the potential impact of NOTAMs on a mission. These can be roughly characterized in terms of the QCODEs that would be used to represent the comparable categories. The categories are primarily broken down by the type of object being described (runway, taxiway, navigational aid, vertical obstruction, aerodrome, lighting of various types, etc.). For many of these categories we break them down still further by distinguishing between descriptions of closure, unavailability, limitation and more general descriptions of changes in the condition of the objects involved. The set of QCODEs that we have used for this characterization are given below (where we use the suffix LC – which nominally means “CLOSED” for the more general notions of closure, unavailability and limitation. This list does not include all possible QCODEs, but it does include all QCODEs which are commonly used (occur as more than .5% of the total set of NOTAMs). As noted above, if these QCODEs were consistently and accurately applied to NOTAMs, that would go a long way to improving the dissemination of NOTAMs. Unfortunately, almost 50% of the current set of NOTAMs either do not have meaningful QCODEs, or have inaccurate or incomplete QCODEs. One of the major capabilities of the ISQ NOTAMs system is to accurately determine the QCODEs for a much larger set of NOTAMs, currently measured to be about 80%. The QCODE-like categories we use are:

```
QAA, QAC, QAF, QAN, QAP, QAR, QARLC, QAT, QAZ, QCA, QCALC, QCELC, QCG, QCGLC,
QCP, QCPLC, QCS, QCSLC, QCT, QCTLC, QFA, QFALC, QFALT, QFC, QFCLC, QFF,
QFFLC, QFL,QFLLC, QFM, QFMLC, QFTLC, QFU, QFULC, QFW, QFWLC, QGJLC, QI, QKK,
QL, QLA, QLB, QLE,QLP, QLX, QLY, QMALC, QMB, QMH, QMHLC, QMN, QMNLC, QMR,
QMRLC, QMRLC, QMU, QMWLC, QMX, QMXLC, QN, QOA, QOB, QOE, QOLLC, QPA, QPALC,
QPD, QPDLC, QPH, QPI, QPILC, QPM, QPU, QRA, QRD, QRM, QRO, QRP, QRR, QRT,
QSA, QSALC, QSB, QSC, QSE, QSF, QSP, QSSLC, QST, QSTLC, QSV, QSVLC, QWA, QWB,
QWC, QWD, QWE, QWF, QWG, QWL, QWM, QWP, QWZ
```

Much more information is available from the parsed NOTAMs than the listing of categories above implies. Thus, the parsing determines the exact boundaries of airspace specified in a NOTAM, enabling reasoning systems to determine whether a given NOTAM is likely to impact a given flight plan or its alternates. Additionally, the parsing makes it clear which runways are affected by closures – which can make a big difference for various types of aircraft. The parsing identifies which instrument procedures are being modified, which exact navigational aids are being referred to, and what has changed.

Conclusions and Transitions

NGA NOTAMs Effort

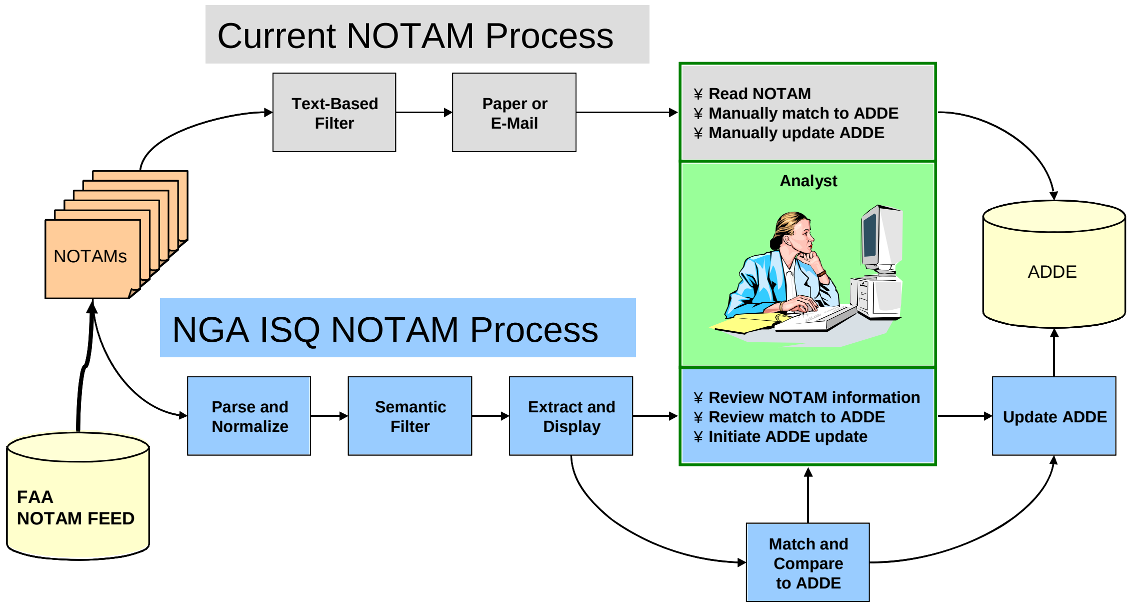

Figure 15: Augmenting the NGA NOTAM process with OWL-NOTAMs

As part of this contract, BBN explored the applicability of the ISQ NOTAMs technology to problems at NGA. We designed, prototyped, and in conjunction with an NGA nominated partner IMAPS, delivered an initial capability to use the ISQ NOTAMs technology to update the NGA corporate worldwide database of vertical obstructions, based on incoming NOTAMs.

This required a number of extensions to the effort done under the base effort. As part of the initial proof of concept effort we performed work in the following areas:

NOTAM acquisition

NGA operates in a classified environment. It has developed a special mechanism to obtain NOTAMs from the FAA and make them available within NGA. The resulting NOTAM feed is not accessible as a web-based system. We initially tested the development of the NGA capability by giving them access to the external BBN NOTAMs server, which operated as a parsing server and obtained NOTAMs from the AMC NOTAM cache. This system was replaced by a system which obtained NOTAMs by the direct retrieval from NGA's Aeronautical Migration System (AMS), a Microsoft Access database of NOTAMs obtained from the FAA. In the process we discovered that there were minor but initially problematic differences between the structure of NOTAMs seen in the NGA feed and those obtained through the AMC NOTAM cache. We resolved these issues and produced a system that allowed the BBN parser to be operated entirely inside NGA.

Vertical Obstruction Parsing Improvements

While we parsed NOTAMs that contained information about Vertical Obstructions, the detailed information in these NOTAMs did not affect the types of decisions made by flight managers, and thus they were not the highest priority for AMC. While the initial parsing coverage was good, we worked to improve extraction of specific information obstacle type, location specification, and altitude specification.

User Interface for VO NOTAM evaluation

In order to incorporate the results of our parsing into the NGA workflow we designed and implemented a new user interface to show NGA analysts the relation between the raw NOTAM text and the extracted location and height. This interface was patterned after the existing interface used to input information into DVOF (Digital Vertical Obstruction File), and provided the necessary ability for skilled human review of the results of the parsing and semantic representation process before the resulting information was input to DVOF.

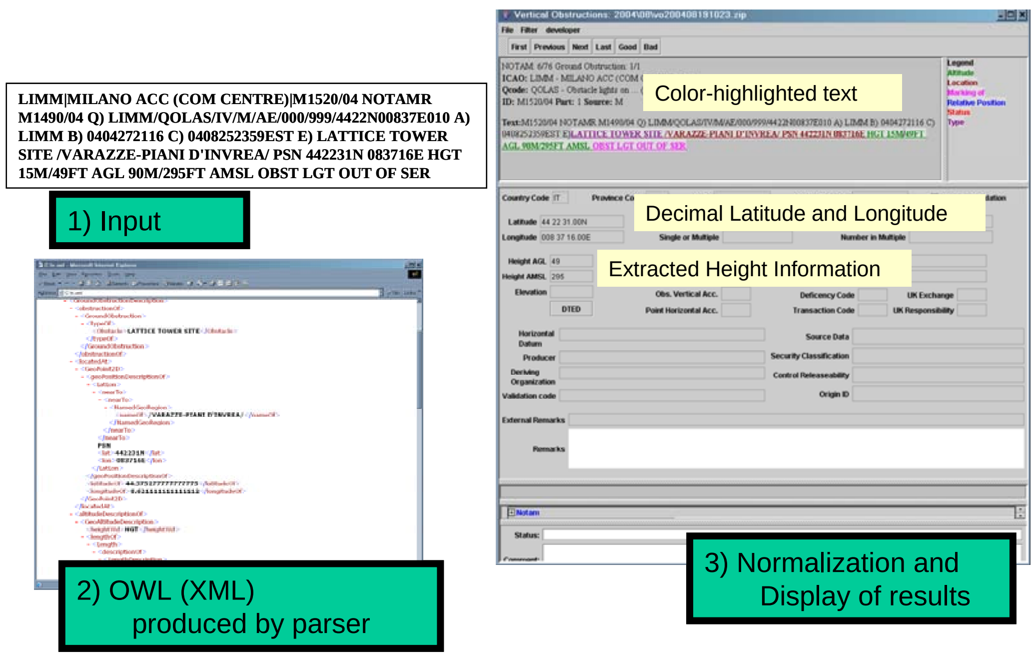

Figure 16: Process for handling DVOF NOTAMs at NGA with OWL-NOTAMs

Interface to DVOF input mechanism

With NGA's help we designed and implemented a mechanism to input into DVOF the parsing results, as verified by an analyst.

In support of an operational prototype system, BBN worked with NGA and IMAPS to separate the ISQ NOTAMs code into two components, the parsing engine ("server") and display and DVOF (Digital Vertical Obstruction File) formatter ("client") components. BBN worked with IMAPS to allow them to produce a version of the client software which they could readily maintain at NGA.

Recommendations

Relationship to an alternative approach to providing these capabilities

We started this effort with the following goal: make NOTAMs understandable by machine. We have demonstrated that if programs can reason about the content of NOTAMs, then we can provide: intelligent dissemination, mapping, alerting and airspace database update

Over the course of this effort it became clear that there were two basic approaches to providing this capability:

1) Provide tools for precisely formatted NOTAM input (e.g. XML standard such as AIXM) and encourage (enforce) their use
2) Take existing NOTAM stream and produce annotations on the NOTAMs that represent their content in machine understandable form (e.g. AIXM)

Approach 1 is available only to official agencies like the FAA or EUROCONTROL, who have official control over the activities of NOTAMs issuers. Approach 2 is the one we have taken. Clearly, if approach 1 is applied in a uniform worldwide manner, then approach 2 would no longer be necessary. Much progress is being made on approach 1, with the promulgation of the AIXM standard by EUROCONTROL, the decision by the FAA and NGA to support this standard, and the later decision by ICAO to accept this approach. Unfortunately, this is a very long term project. Even in Europe, which made the decision to move towards AIXM, a standard for NOTAMs has still not been approved. Building of systems to help people issue NOTAMs according to that standard will then require substantial funding and development. It is not expected that this will take place for at least another ten years. Making such technology available and enforcing its use around the world will pose many other technical, financial and particularly political hurdles. Finally, as is clear from the use of automated NOTAMs entry tools within the US DoD, any such tool must contain ways to break out of the standardized format to report truly unusual situations – and this leaves open the possibility (likelihood) that many NOTAMs will be issued in a non-standard form. Thus, it is our firm belief that ***for the foreseeable future it will be necessary to combine the two approaches***.

Appendix A – Transition Opportunities

1 Transition Opportunities

1.1 Introduction

During the course of the research first initiated in 2003, BBN worked with Mr. DePalma and representatives of AMC, Hanscom AFB, AFRL, Jeppesen, EUROCONTROL, and the FAA to determine appropriate transition opportunities for the NOTAMs capabilities. Below, we list the transitions that BBN has worked on, as well as future opportunities that are currently in progress.

1.2 NGA DVOF

In 2003, BBN began discussions with part of the National Imagery and Mapping Agency (later known as the National Geospatial-Intelligence Agency) to use the parsing and reasoning capabilities of BBN's NOTAMs work within their organization. Working with Chuck McGaugh and Barry Herbert, BBN was able to define an integration path that allowed BBN to set up a NOTAMs server that would parse and identify NOTAMs that corresponded to vertical obstructions – man-made obstructions such as towers, buildings, radio masts, and power lines, which need to be monitored and managed through the Digital Vertical Obstruction File. BBN developed a GUI that would allow NGA analysts to review these vertical obstruction NOTAMs with key fields parsed and highlighted, modify them as necessary, and output them for inclusion in the formal DVOF database.

NGA identified IMAPS, LLC of St. Louis (now a part of SAIC) as the integration contractor, who would be responsible for transitioning the initial capability, installing the NOTAMs server and rewriting the GUI for use at NGA. BBN has worked closely with IMAPS with this transition, and initial transition was scheduled for the end of March 2006.

1.3 JMPS/NOTAMs Integration

Through discussions with AFRL, Hanscom ESC, and AMC, BBN received an additional $500k of funding in early 2005 to transition the NOTAMs capability into AMC through integration with the JMPS mission planning tools. BBN worked closely with TYBRIN Corporation, BAE Systems, and Computer Sciences Corporation to develop the initial capabilities, where BBN would provide a web services interface for JMPS to query. JMPS would provide BBN's web service with a Common Route Definition file that contained a route of interest to mission planners, and BBN's parsing and reasoning capabilities would determine which NOTAMs would be of interest based on route segments and identification of waypoints, airfields, and navaids using geospatial reasoning capabilities. NOTAMs of interest are returned to JMPS, which are then graphically displayed on a map, and made available to mission planners through a tree view capability.

1.4 GPCC

These integration efforts continued through the Global Planning Common Component program, also with TYBRIN Corporation, where the NOTAMs server and web services were defined as common components in the new architecture. Under this program, the integration between BBN's NOTAMs capabilities and JMPS was tightened, the parser accuracy was heightened through constant interaction between TYBRIN and BBN, and the GPCC-identified testing squadron was able to provide additional areas for improvement, both within the GUI itself, and with presentation of NOTAMs and additional parsing issues to improve accuracy. This program will result in a NOTAMs parser installed at AMC within the Tanker Airlift Control Center (TACC) enclave.

This work continues through 2006, with the focus on the effort being through the categorization of NOTAMs, allowing flight planners to define their own categories to organize NOTAMs into different levels of severity. BBN is also working closely with TYBRIN and the FAA to install and maintain a parser within the FAA, alongside DINS – the GPCC effort will ultimately transition from using a parser co-located in the TACC to the parser hosted at the FAA, which can then be accessed from any number of authorized locations without the need for multiple parser instances. In addition, BBN is developing capabilities to parse and reason over additional data sources, such as graphical Temporary Flight Restrictions (TFRs), Special Use Airspaces (SUAs), and data from the Enhanced Traffic Management System (ETMS), which will be made available to JMPS.

This capability is scheduled for summer 2006, with delivery to AMC scheduled in late 2006.

Appendix B - Future Research/Transition Opportunities: TASM

In addition to the GPCC effort, BBN is collaborating with TYBRIN Corporation, Northrop Grumman, and the Georgia Tech Research Institute on the TASM program, part of the MPEC delivery order out of Hanscom AFB. In this program, BBN's NOTAMs capabilities will continue to be made available as a common component through GPCC, and BBN will be involved integration efforts through the 2009 timeframe and beyond.

Appendix C - Lists of Symbols, Abbreviations, and Acronyms

AFMC	Air Force Materiel Command
AFRL	Air Force Research Lab
AIXM	Aeronautical Information Exchange Model
AMC	Air Mobility Command
AMS	Aeronautical Migration System
ARTCC	Air Route Traffic Control Center
ATD	Advanced Technology Demonstration
COTR	Contracting Officer’s Technical Representative
DAFIF	Digital Aeronautical Flight Information File
DAML	DARPA Agent Markup Language
DINS	Defense Internet NOTAM Service
DoD	Department of Defense
DVOF	Digital Vertical Obstruction File
ESC	Electronic Systems Command
EUROCONTROL	European Organisation for the Safety of Air Navigation
FAA	Federal Aviation Agency
FIR	Flight Information Region
FIST	Finite State Transducer
FM	Flight Manager
GAMAT	Global Air Mobility Advanced Technology
GDSS	Group Decision Support System
GPCC	Global Planning Common Component
GUI	Graphical User Interface
ICAO	International Civil Aviation Organization
IdiON	Intelligent Distribution of NOTAMs
IFM	Integrated Flight Management
IMT	Integrated Management Tool
IR&D	Internal Research and Development
JMPS	Joint Mission Planning System
KFDC	ICAO code for Washington, DC
MAF-CAF	Mobility Air Forces – Combat Air Forces
METAR	Meteorological Aviation Report
NAIMES	NAS Aeronautical Information Management Enterprise System
NAS	National Airspace System
NGA	National Geospatial-Intelligence Agency
NIMA	National Imagery and Mapping Agency
NOTAM	Notice to Airman
OIL	Ontology Integration Language
OWL	Web Ontology Language
PI	Principal Investigator
PIREP	Pilot Report
RDF	Resource Description Framework
SES	Senior Executive Service
TACC	Tanker Airlift Control Center
UIR	Upper Flight Information Report
VTACC	Virtual Tanker Airlift Control Center
W3C	World Wide Web Consortium
WCSS	Work Centered Support Systems
XML	Extensible Markup Language

Appendix D - QCODE definitions:

QCODE 2nd & 3rd LETTERS

(A) Airspace Organization
(C) Communications and Radar
(F) Facilities and Services
(G) Military
(I) Instrument and Microwave Landing
(L) Lighting
(M) Movement and Landing Area
(N) Terminal and En-route Navigation
(O) Other Information
(P) Air Traffic Procedures
(R) Airspace Restrictions
(S) Air Traffic and VOLMET Services
(T) Hazard
(W) Warnings
(X) Other

Airspace Organization (A)

AA	MINIMUM ALTITUDE
AC	CONTROL ZONE
AD	ADIZ
AE	CONTROL AREA
AF	FLIGHT INFORMATION REGION (FIR)
AG	GENERAL FACILITY
AH	UPPER CONTROL AREA
AL	MINIMUM USABLE FLIGHT LEVEL
AN	AIR NAVIGATION ROUTE
AO	OCEANIC CONTROL ZONE (OCA)
AP	REPORTING POINT
AR	ATS ROUTE
AT	TERMINAL CONTROL AREA (TMA)
AU	UPPER FLIGHT INFORMATION REGION
AV	UPPER ADVISORY AREA
AX	INTERSECTION
AZ	AERODROME TRAFFIC ZONE (ATZ)

Top

Communications and Radar (C)

CA	AIR/GROUND FACILITY
CE	ENROUTE SURVELLENCE RADAR
CG	GROUND CONTROLLED APPROACH SYSTEM (GCA)
CL	SELECTIVE CALLING SYSTEM
CM	SURFACE MOVEMENT RADAR
CP	PAR
CR	SURVEILLANCE RADAR ELEMENT OF PAR SYSTEM
CS	SECONDARY SURVEILLANCE RADAR

CT	TERMINAL AREA SURVEILLANCE RADAR

Top

Facilities and Services (F)

FA	AERODROME
FB	BRAKING ACTION MEASUREMENT EQUIPMENT
FC	CEILING MEASUREMENT EQUIPMENT
FD	DOCKING SYSTEM
FF	FIRE FIGHTING AND RESCUE
FG	GROUND MOVEMENT CONTROL
FH	HELICOPTER ALIGHTING AREA/PLATFORM
FL	LANDING DIRECTION INDICATOR
FM	METEOROLOGICAL SERVICE
FO	FOG DISPERSAL SYSTEM
FP	HELIPORT
FS	SNOW REMOVAL EQUIPMENT
FT	TRANSMISSOMETER
FU	FUEL AVAILABILITY
FW	WIND DIRECTION INDICATOR
FZ	CUSTOMS

Top

Military (G)

GA	PULSATING/STEADY VISUAL APPROACH SLOPE INDICATOR
GB	OPTICAL LANDING SYSTEM
GC	TRANSIENT MAINTENANCE
GD	STARTER UNIT
GE	SOAP
GF	DEMINERALIZED WATER
GG	OXYGEN
GH	OIL
GI	DRAG CHUTES
GJ	ASR
GK	PRECISION APPROACH LANDING SYSTEM
GL	FACSFAC
GM	LOCALIZER
GO	WARNING AREA
GP	MILITARY OPERATIONS AREA (MOA)
GR	DIVERSE DEPARTURE
GS	NITROGEN
GT	IFR TAKE-OFF MINIMUMS AND DEPARTURE PROCEDURES
GU	DE-ICE
GZ	BASE OPERATIONS

Top

Instrument and Microwave Landing (I)

IC	ILS
ID	DME ASSOCIATED WITH ILS
IG	GLIDE PATH (ILS)
II	INNER MARKER (ILS)

IL	LOCALIZER (ILS)
IM	MIDDLE MARKER (ILS)
IO	OUTER MARKER (ILS)
IS	ILS CATEGORY I
IT	ILS CATEGORY II
IU	ILS CATEGORY III
IW	MLS
IX	LOCATOR, OUTER, (ILS)
IY	LOCATOR, MIDDLE (ILS)

Top

Lighting (L)

LA	APPROACH LIGHTING SYSTEM
LB	AERODROME BEACON
LC	RUNWAY CENTERLINE LIGHTS
LD	LANDING DIRECTION INDICATOR LIGHTS
LE	RUNWAY EDGE LIGHTS
LF	SEQUENCED FLASHING LIGHTS
LH	HIGH INTENSITY RUNWAY LIGHTS
LI	RUNWAY END IDENTIFIER LIGHTS
LJ	RUNWAY ALIGNMENT INDICATOR LIGHTS
LK	CATEGORY II COMPONENTS OF APPROACH LIGHTING SYSTEM
LL	LOW INTENSITY RUNWAY LIGHTS
LM	MEDIUM INTENSITY RUNWAY LIGHTS
LP	PRECISION APPROACH PATH INDICATOR
LR	ALL LANDING AREA LIGHTING FACILITIES
LS	STOPWAY LIGHTS
LT	THRESHOLD LIGHTS
LV	VISUAL APRROACH SLOPE INDICATOR
LW	HELIPORT LIGHTING
LX	TAXIWAY CENTER LINE LIGHTS
LY	TAXIWAY EDGE LIGHTS
LZ	RUNWAY TOUCH DOWN ZONE LIGHTS

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Movement and Landing Area (M)

MA	MOVEMENT AREA
MB	BEARING STRENGTH
MC	CLEARWAY
MD	DECLARED DISTANCES
MG	TAXIING GUIDANCE SYSTEM
MH	RUNWAY ARRESTING GEAR
MK	PARKING AREA
MM	DAYLIGHT MARKINGS
MN	APRON
MP	AIRCRAFT STANDS
MR	RUNWAY
MS	STOPWAY
MT	THRESHOLD
MU	RUNWAY TURNING BAY
MW	STRIP

MX	TAXIWAY

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Terminal and En-route Navigation (N)

NA	ALL RADIO NAVIGATION FACILITIES
NB	NDB
NC	DECCA
ND	DME
NF	FAN MARKER
NL	LOCATOR
NM	VOR/DME
NN	TACAN
NT	VORTAC
NV	VOR
NX	DIRECTION FINDING STATION

Top

Other Information (O)

OA	AERONAUTICAL INFORMATION SERVICE
OB	OBSTACLE
OE	AIRCRAFT ENTRY REQUIREMENTS
OL	OBSTACLE LIGHTS
OR	RESCUE COORDINATION CENTER

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Air Traffic Procedures (P)

PA	STANDARD INSTRUMENT ARRIVAL (STAR)
PD	STANDARD INSTRUMENT DEPARTURE (SID)
PF	FLOW CONTROL PROCEDURES
PH	HOLDING PROCEDURES
PI	INSTRUMENT APPROACH PROCEDURE
PL	OBSTACLE CLEARANCE LIMIT
PM	AERODROME OPERATING MINIMA
PO	OBSTACLE CLEARANCE ALTITUDE
PP	OBSTACLE CLEARANCE HEIGHT
PR	RADIO FAILURE PROCEDURE
PT	TRANSITION ALTITUDE
PU	MISSED APPROACH PROCEDURE
PX	MINIMUM HOLDING ALTITUDE
PZ	ADIZ PROCEDURE

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Airspace Restrictions (R)

RA	AIRSPACE RESERVATION
RD	DANGER AREA
RO	OVERFLYING OF
RP	PROHIBITED AREA
RR	RESTRICTED AREA
RT	TEMPORARY RESTRICTED AREA

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Air Traffic and VOLMET Services (S)

SA	AUTOMATIC TERMINAL INFORMATION SERVICE (ATIS)
SB	ATS REPORT OFFICE
SC	AREA CONTROL CENTER
SE	FLIGHT INFORMATION SERVICE
SF	AERODROME FLIGHT INFORMATION SERVICE (AFIS)
SL	FLOW CONTROL CENTER
SO	OCEANIC AREA CONTROL CENTER
SP	APPROACH CONTROL
SS	FLIGHT SERVICE STATION
ST	AERODROME CONTROL TOWER
SU	UPPER AREA CONTROL CENTER
SV	VOLMENT BROADCAST
SY	UPPER ADVISORY SERVICE

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Hazard (T)

TT	MIJI

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Warnings (W)

WA	AIR DISPLAY
WB	AEROBATICS
WC	CAPTIVE BALLOON OR KITE
WD	DEMOLITION OF EXPLOSIVES
WE	EXERCISES
WF	AIR REFUELING
WG	GLIDER FLYING
WJ	BANNER/TARGET TOWING
WL	ASCENT OF FREE BALLOON
WM	MISSLE, GUN OR ROCKET FIRING
WP	PARACHUTE JUMPING EXERCISE
WS	BURNING OR BLOWING GAS
WT	MASS MOVEMENT OF ACFT
WV	FORMATION FLT
WZ	MODEL FLYING

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Other (X)

XX	PLAIN LANGUAGE

QCODE 4th & 5th LETTERS

(A) Availability
(C) Change
(G) Military
(H) Hazard Conditions
(L) Limitations
(X) Other

Availability (A)

AC	WITHDRAWN FOR MAINTENANCE
AD	AVAILABLE FOR DAYLIGHT OPERATIONS
AF	FLIGHT CHECKED AND FOUND RELIABLE
AG	OPERATING BUT GROUND CHECKED ONLY, AWAITING FLIGHT CHECK
AH	HOURS OF SERVICE ARE
AK	RESUMED NORMAL OPERATIONS
AM	MILITARY OPERATIONS ONLY
AN	AVAILABLE FOR NIGHT OPERATIONS
AO	OPERATIONAL
AP	PRIOR PERMISSION REQUIRED
AR	AVAILABLE, PRIOR PERMISSION REQUIRED
AS	UNSERVICEABLE
AU	NOT AVAILABLE
AW	COMPLETELY WITHDRAWN
AX	PREVIOUSLY PROMULGATED SHUTDOWN HAS BEEN CANCELLED

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Change (C)

CA	ACTIVATED
CC	COMPLETED
CD	DEACTIVATED
CE	ERECTED
CF	FREQUENCY CHANGED TO
CG	DOWNGRADED TO
CH	CHANGED
CI	IDENTIFICATION OR RADIO CALL SIGN CHANGED TO
CL	REALIGNED
CM	DISPLACED
CO	OPERATING
CP	OPERATING ON REDUCED POWER
CR	TEMPORARILY REPLACED BY
CS	INSTALLED
CT	ON TEST, DO NOT USE

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Military (G)

GA	NOT COINCIDENTAL WITH ILS/PAR
GB	IN RAISED POSITION
GC	TAIL HOOK ONLY
GD	OFFICIAL BUSINESS ONLY

GE	EXPECT LANDING DELAY
GF	EXTENSIVE SERVICE DELAY
GG	UNUSABLE BEYOND
GH	UNUSABLE
GI	UNMONITORED
GV	NOT AUTHORIZED

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Hazard Conditions (H)

HA	BRAKING ACTION IS
HB	BRAKING COEFFICIENT IS
HC	COVERED BY COMPACTED SNOW TO A DEPTH OF
HD	COVERED BY DRY SNOW TO A DEPTH OF
HE	COVERED BY WATER TO A DEPTH OF
HF	TOTALLY FREE OF SNOW AND ICE
HG	GRASS CUTTING IN PROGRESS
HH	HAZARD DUE TO
HI	COVERED BY ICE
HJ	LAUNCH PLANNED
HK	MIGRATION IN PROGRESS
HL	SNOW CLEARANCE COMPLETED
HM	MARKED BY
HN	COVERED BY WET SNOW OR SLUSH TO A DEPTH OF
HO	OBSCURED BY SNOW
HP	SNOW CLEARANCE IN PROGRESS
HQ	OPERATIONS CANCELLED
HR	STANDING WATER
HS	SANDING
HT	APPROACH ACCORDING TO SIGNAL AREA ONLY
HU	LAUNCH IN PROGRESS
HV	WORK COMPLETED
HW	WORK IN PROGRESS
HX	CONCENTRATION OF BIRDS
HY	SNOW BANKS EXIST
HZ	COVERED BY FROZEN RUTS AND RIDGES

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Limitations (L)

LA	OPERATING ON AUXILIARY POWER SUPPLY
LB	RESERVED FOR AIRCRAFT BASED THEREIN
LC	CLOSED
LD	UNSAFE
LE	OPERATING WITHOUT AUXILIARY POWER SUPPLY
LF	INTERFERENCE FROM
LG	OPERATING WITHOUT IDENTIFICATION
LH	UNSERVICEABLE FOR AIRCRAFT HEAVIER THAN
LI	CLOSED TO IFR OPERATIONS
LK	OPERATING AS A FIXED LIGHT
LL	USABLE FOR LENGTH OF AND WIDTH OF
LN	CLOSED TO ALL NIGHT OPERATIONS
LP	PROHIBITED TO

LR	AIRCRAFT RESTRICTED TO RUNWAYS AND TAXIWAYS
LS	SUBJECT TO INTERRUPTION
LT	LIMITED TO
LV	CLOSED TO VFR OPERATIONS
LW	WILL TAKE PLACE
LX	OPERATING BUT CAUTION ADVISED DUE TO
LY	EFFECTIVE
TT	HAZARD

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Other (X)

XX	PLAIN LANGUAGE

Alphabetical list of OWL Concepts used by the ISQ NOTAMs System

ATSReportingOffice
ATSRoute
ATSRouteActivation
ATSRouteClosed
ATSRouteStatusReport
ATZStatus
ATZStatusReport
AUSIdentifier
Activated
Active
AerialDisplay
AerialDisplayStatusReport
AerialObstacle
AerialObstacleStatusReport
Aerobatics
AerobaticsStatusReport
AerodromeBeacon
AerodromeBeaconStatus
AerodromeClosed
AerodromeClosedReport
AerodromeCommunicationFacility
AerodromeCommunicationFacilityFrequencySpec
AerodromeCommunicationFacilityOutOfService
AerodromeCommunicationFacilityStatusReport
AerodromeControlTower
AerodromeControlTowerFrequencySpec
AerodromeControlTowerOutOfService
AerodromeControlTowerStatusReport
AerodromeFlightInformationService
AerodromeFlightInformationServiceFrequencySpec
AerodromeFlightInformationServiceOutOfService
AerodromeFlightInformationServiceStatusReport
AerodromeHoursOfService
AerodromeLimitedReport
AerodromeReferencePoint
AerodromeServiceStatus
AerodromeStatusReport
AipPublication
AipSection
AirRefueling
AirSpeedRestriction
AirTrafficProcedureStatus
AircraftCrossing
AircraftMDS
AircraftStand
Airfield
Airport
AirspaceEntryPermission
AirspaceOrganization
AirspaceOrganizationStatus
AirspaceReservation
AirspaceReservationActivationReport
AirspaceReservationHead
AirspaceReservationPhrase
AirspaceReservationStatus
AlongBoundary
AltitudeMinimum
AltitudeReservation
AltitudeReservationStatusReport
Antenna
AntennaStructureRegistration
ApproachControlService
ApproachControlServiceFrequencySpec
ApproachControlServiceOutOfService
ApproachControlServiceStatusReport
ApproachControlServices
ApproachMinimums
ApproachType
ApprovalRequired
Apron
ApronClosed
ApronStatus
AreaControlCenter
AreaControlCenterFrequencySpec
AreaControlCenterOutOfService
AreaControlCenterStatusReport
ArrestingGear
ArrestingGearStatus
ArrestingGearStatusReport
ArrestingGearType
ArrestingGearUnavailableReport
AscentOfFreeBalloons
AscentOfFreeBalloonsStatusReport
AutomaticTerminalInformationService
AutomaticTerminalInformationServiceFrequencySpec
AutomaticTerminalInformationServiceOutOfService
AutomaticTerminalInformationServiceStatusReport
Available
Bearing
BearingStrength
Belfry
BirdWatchCondition
Bridge
Building
CTRAirspace

Cable
CaptiveBalloonOrKite
CaptiveBalloonOrKiteStatusReport
CardinalDirection
Category
CategoryMinimumAltitude
CategoryVisibilityMinimum
Caused
CautionWarning
Chimney
ClassA_Airspace
ClassBAirspace
ClassBAirspaceStatusReport
ClassBAirspaceUnavailableStatusRepo
rt
ClassB_Airspace
ClassC_Airspace
ClassD_Airspace
ClassE_Airspace
ClassF_Airspace
ClassG_Airspace
ClimbInstructions
ClockTime
Closed
CommsHoursOfService
CommsOutOfService
CommunicationFrequencySpec
CommunicationFrequencyStatus
Corridor
Country
Crane
DFEquipment
DMEArcProcedure
DMEDistance
DMEEquipment
DMEStatusReport
DMEUnavailableReport
DangerAirspaceHead
DangerArea
DangerAreaActivated
DangerAreaActivationReport
DangerAreaStatus
Date
Day
DayNight
DayOfWeek
Delay
DelimitedName
DemolitionOfExplosives
DimensionDescription
Drilling
DropZone
EnrouteNavigationFacility
EnrouteSurveillanceRadar
EnrouteSurveillanceRadarFacilitySta
tusReport
EnrouteSurveillanceRadarFacilityUna
vailableStatusReport
Exercise
ExerciseStatusReport
FDCAnnouncement
Facility
FireFightingCapabilityStatusReport
FireFightingCapabilityUnavailableRe
port
FlightLevel
FlightRestriction
Fraction
FrequencyDescription
FuelAvailabilityStatus
FuelCapability
FuelCapabilityStatusReport
GCARadarFacility
GCARadarFacilityStatusReport
GCARadarFacilityUnavailableStatusRe
port
GeoAltitude
GeoAltitudeDescription
GeoAltitudeRange
GeoBox
GeoPoint2D
GeoRegion
GeoVector
GlidePathStatus
GlidePathStatusReport
GlidePathUnavailableReport
Glider
GliderLandingSite
GliderStatusReport
GlobalPositioningSystem
GridPosition
GroundObstruction
GroundObstructionDescription
GroundObstructionLightStatusReport
Hangar
Header
Hole
HoursOfService
ILSCategoryIIIUnavailableReport
ILSCategoryIIStatusReport
ILSCategoryIIUnavailableReport
ILSCategoryIStatusReport
ILSCategoryIUnavailableReport
ILSEquipment
ILSGlidePath
ILSLocalizer
ILSMarker
ILSStatus

ILS_DMEStatus
ILS_DMEStatusReport
ILS_DMEUnavailableReport
ILS_MLSFacilityCatI
ILS_MLSFacilityCatII
ILS_MLSFacilityCatIII
ILSdme
InstrumentApproachProcedure
InstrumentApproachProcedureStatus
InstrumentApproachProcedureStatusReport
InstrumentApproachProcedureUnavailableReport
InstrumentApproachProcedureUnavailableStatus
InstrumentApproachProcedures
Intensity
IntervalDescription
IssuedByICAO
LatLon
LatLonSeq
Length
LengthDescription
Light
Lighted
LimitedFlights
LocalizerStatus
LocalizerStatusReport
LocalizerStatusUnavailableReport
MLSEquipment
MLSStatusReport
MLSUnavailableReport
MarkerStatusReport
MarkerStatusUnavailableReport
Mast
MeteorologicalEquipment
MeteorologicalEquipmentOutOfService
MeteorologicalEquipmentStatusReport
MeteorologicalServiceStatus
MiddleMarkerStatus
MilitaryExerciseStatus
MilitaryNotamIds
MinimumAltitude
MissileGunRocketFiring
MissileGunRocketFiringStatusReport
ModelFlying
ModelFlyingStatusReport
MultiIntervalDescription
NDBEquipment
NOTAMChecklist
NamedGeoRegion
Navaid
NavaidStatus
NavaidStatusReport
NavaidUnavailable
NavaidUnavailableReport
NavigationUpdateCapability
NearBy
NearLatLon
NearRamp
NearRunway
NearTaxiway
Night
NormalizedDAML
Notam
NotamPartAnnouncement
NotamReason
NotamReference
Notams
OTSStatus
Obstacle
ObstacleClearance
ObstacleLighted
ObstacleLightsOTS
ObstacleMarked
ObstacleQCode
ObstacleUnlighted
ObstacleWd
ObstructionWillBeLowered
Oilrig
OverflightRestrictionStatusReport
PCNSpec
PacotsTrackAnnouncement
ParachuteJumping
ParachuteJumpingStatusReport
ParkingAreaClosed
ParkingAreaStatus
PermanentFlightInformation
Piling
Pole
PolygonDescription
PriorPermission
ProhibitedAirspace
ProhibitedAirspaceActivated
ProhibitedAirspaceActivationReport
ProhibitedAirspaceHead
Pylon
QATStatus
QCEStatus
QSaHoursOfService
QSaOutOfService
QScHoursOfService
QSeHoursOfService
QSeOutOfService
QSfHoursOfService
QSfOutOfService
QSpHoursOfService
QSpOutOfService

QSsHoursOfService
QSsOutOfService
QStHoursOfService
QStOutOfService
QSvHoursOfService
QSvOutOfService
QuietHours
RNAVigation
RVSMairspaceAnnouncement
Radar
RadarFacilitiesUnavailableStatus
RadarFacility
RadarFacilityStatusReport
RadarFacilityUnavailableStatusRepor
t
RadialDMEPosition
RadialRegion
RadiusSpec
Ramp
RampEdge
RampEnd
ReferenceTemperatureChange
RelativeLocation
ReportingPoint
RequiredNavigationPerformanceAnnoun
cement
RestrictedAirspace
RestrictedAirspaceActivated
RestrictedAirspaceActivationReport
RestrictedAirspaceHead
RestrictedAreaStatus
RouteAvailabilityDocument
Runway
RunwayAlignmentIndicatorLights
RunwayAlignmentIndicatorLightsType
RunwayAlignmentIndicatorStatus
RunwayAlignmentIndicatorStatusRepor
t
RunwayAlsLighting
RunwayAlsLightingType
RunwayApproach
RunwayApproachStatusReport
RunwayBearingStrength
RunwayCenterline
RunwayCenterlineLightStatus
RunwayCenterlineLightStatusReport
RunwayCenterlineLights
RunwayCenterlineLightsType
RunwayClosed
RunwayClosedReport
RunwayCondition
RunwayDeclaredDistance
RunwayEdge
RunwayEdgeLightStatus
RunwayEdgeLightStatusReport
RunwayEdgeLights
RunwayEdgeLightsType
RunwayEnd
RunwayEndIdentifierLightStatus
RunwayEndIdentifierLightStatusRepor
t
RunwayEndIdentifierLights
RunwayEndIdentifierLightsType
RunwayHighIntensityLightsType
RunwayImpact
RunwayInstrumentSystemStatus
RunwayInstrumentSystemStatusReport
RunwayLandingDirectionIndicatorStat
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RunwayLandingDirectionIndicators
RunwayLandingDirectionIndicatorsTyp
e
RunwayLightingAlsStatus
RunwayLightingAlsStatusReport
RunwayLightingStatus
RunwayLightingStatusReport
RunwayLightingSystem
RunwayLightingSystemType
RunwayLowIntensityLightStatusReport
RunwayLowIntensityLights
RunwayLowIntensityLightsType
RunwayMediumIntensityLightStatusRep
ort
RunwayMediumIntensityLights
RunwayMediumIntensityLightsType
RunwayMeteorologicalEquipmentStatus
Report
RunwayPAPILights
RunwayPAPILightsType
RunwayPAPIStatus
RunwayPAPIStatusReport
RunwayPhysicalCharacteristics
RunwayRadar
RunwayRadarFacility
RunwayRadarStatus
RunwayRadarStatusReport
RunwayRadarUnavailableStatus
RunwayRadarUnavailableStatusReport
RunwayRemainingDistanceMarker
RunwayRemainingDistanceMarkerStatus
RunwayRestrictedStatusReport
RunwaySegment
RunwaySegmentClosedReport
RunwaySegmentUnavailableReport
RunwaySequencedFlashingLightStatus
RunwaySequencedFlashingLightStatusR
eport
RunwaySequencedFlashingLightsType

RunwayStatus
RunwayStatusReport
RunwayStopwayLightStatusReport
RunwayStopwayLights
RunwayStopwayLightsType
RunwayStrip
RunwayThreshold
RunwayThresholdDisplaced
RunwayThresholdLightStatusReport
RunwayThresholdLights
RunwayThresholdLightsType
RunwayUnavailable
RunwayUnavailableReport
RunwayVASILightStatusReport
RunwayVASILights
RunwayVASILightsType
RunwayWeatherHazardStatus
RunwayWeatherSurfaceConditionReport
RunwayWorkInProgressReport
SSRFacility
SSRFacilityStatusReport
SSRFacilityUnavailableStatusReport
SUAHead
Sector
ShipPassAcross
SpecialNotice
SpecialUseAirspace
SpecialUseAirspaceActivated
SpecialUseAirspaceActivationReport
SpecialUseAirspaceHead
SpecialUseAirspaceStatus
Stack
StandardArrival
StandardDeparture
StandardInstrumentArrivalStatus
StandardInstrumentArrivalUnavailable
StandardInstrumentDepartureStatus
StandardInstrumentDepartureStatusReport
StandardInstrumentDepartureUnavailable
StandardInstrumentDepartureUnavailableStatusReport
SurveillanceRadar
TACANEquipment
TCCorridor
TDMTrackAnnouncement
TLSEquipment
TWRServices
TakeOffMinimums
TapMUScore
Taxiway
TaxiwayBearingStrength
TaxiwayClosedReport
TaxiwayEdge
TaxiwayLight
TaxiwayLightingStatus
TaxiwayLightingStatusReport
TaxiwayPhysicalCharacteristics
TaxiwaySegment
TaxiwayStatus
TaxiwayStatusReport
TaxiwayUnavailableReport
TelephoneNumber
Temperature
TemporaryFlightInformation
TemporaryFlightRestriction
TemporaryRestrictedAirspace
TemporaryRestrictedAirspaceActivated
TemporaryRestrictedAirspaceHead
TerminalAreaSurveillanceRadar
TerminalAreaSurveillanceRadarStatusReport
TerminalAreaSurveillanceRadarUnavailable
TerminalAreaSurveillanceRadarUnavailableStatusReport
Terrain
Tower
Traffic
TrafficManagementProgramAlert
Transition
Transmissometer
TransmissometerOutOfService
TransmissometerStatus
TransmissometerStatusReport
TransmissometerUnavailableReport
Tree
TurningBay
USRegulationPublication
Unavailable
Unlit
VOREquipment
VORStatus
VORTACEquipment
VORUnavailable
VisibilityLengthDescription
VisualApproachProcedure
VisualMeteorologicalConditions
VolcanicCloudReport
VorDmeEquipment
VorDmeStatusReport
VorDmeUnavailableReport
Waas
WarningArea
WarningAreaActivated

WayPointSeq
Waypoint
WeatherReportingFacility
WeatherReportingFacilityFrequencySpec
WeatherReportingFacilityOutOfService
WeatherReportingFacilityStatusReport
WindDirectionEquipmentOutOfService
WindDirectionEquipmentStatusReport
WindDirectionIndicator
WindMeasuringEquipment
WindpowerPlant
WingspanRestriction
WorkInProgress
WxRep